

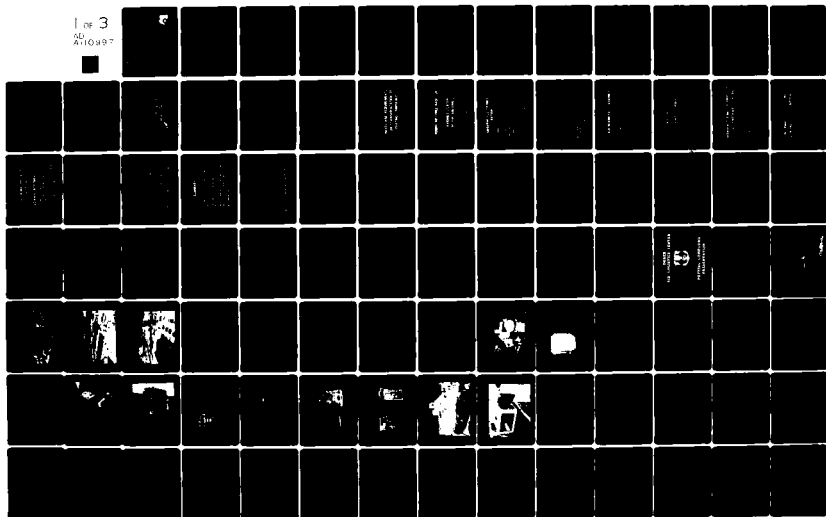
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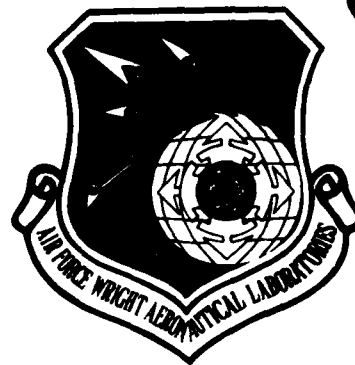


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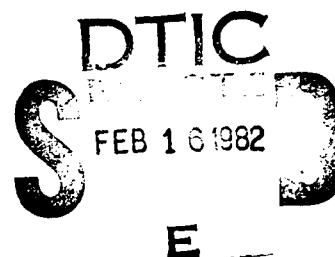
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AIR FORCE/INDUSTRY REPAIRABLE POTTING MATERIALS WORKSHOP

BILL DOBBS

*SYSTEMS ACQUISITION & SUPPORT BRANCH
SYSTEMS SUPPORT DIVISION*



NOVEMBER 1981

TECHNICAL REPORT AFWAL-TR-81-4113
Workshop Proceedings — 15 June 1981

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MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This technical report has been reviewed and is approved for publication.

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Project Engineer
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The ALCs reported that significant quantities of potted electronic modules are discarded simply because it is impossible to repair them. These reports indicate that millions of dollars worth of electronic assemblies or subassemblies are condemned each year because of their inaccessibility to repair. In situations where the module may be de-potted there are too many different types of potting materials and solvents involved. The Air Force has been plagued for years with steadily expanding quantities of potting materials until there are presently several hundred different stock listed compounds and solvents in the inventory.		

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20. The maintenance and storage of these solvents necessary for the removal of the different potting materials are very expensive.

The Repairable Potting Materials Workshop provided an information exchange between customers and manufacturers of potted electronic assemblies for airborne and ground based electronics. The results of this workshop indicate that the Air Force will definitely benefit from standardization of potting materials for electronic assemblies. The reduction in maintenance and condemnation costs will result in an Air Force cost savings of millions of dollars per year.

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PREFACE

The Repairable Potting Materials Workshop was held in conjunction with the National Electronic Packaging and Production Conference (NEPCON East) June 15, 1981, at the New York City Coliseum, NY. The purpose of the workshop was to discuss the possibility of standardizing potting materials used on electronic assemblies for airborne and ground-base electronics. This area is of concern to the Air Force since many problems have been encountered when potted assemblies are improperly repaired. The results of two surveys, one with Industry and the other with Air Force Logistic Centers, were presented. The Industry survey was conducted by the University of Dayton Research Institute and the Air Force survey by ASD/RAOF. The ten member panel gave presentations and panel-audience discussions were held afterward.

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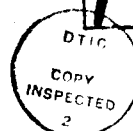


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SECTION I

INTRODUCTION

Recent meetings with government and industry personnel have highlighted the need for advancement and technology transfer in standardization and repair of potted electronic modules. AFWAL/MLSS has worked with PRAM and the ALCs in an attempt to reduce waste by standardizing potting materials and solvents for electronic modules. The ALCs have reported that significant quantities of potted electronic modules are discarded simply because it is impossible to repair them. The ALCs report that this results in a substantial loss to the government. Also, in the Air Force/Industry AD Manufacturing Cost Reduction Study, 4-6 March 1980, the Ordinance Panel identified several problems with potting materials on systems such as the Gator AP, Gator AT and Slufae. In most of these situations too many different types of materials are currently being used and a large portion of them cannot be depotted. Col. Parker, ASD/RA, 10 January 1980, said, "The Air Force has been plagued for years with steadily expanding quantities of potting materials until there are presently several hundred different stock listed compounds and solvents in the inventory to do basically the same job. Many of these compounds can't be removed from electronic components without damaging or destroying the component. Often the compound can't even be identified. Preliminary reports from the ALCs and other government agencies indicate millions of dollars worth of electronic assemblies or subassemblies may be condemned or damaged each year because of their inaccessibility to repair. Incidental to maintenance and condemnation cost may be losses due to decreased reliability and early component failure caused by the thermal or electrical properties of potting compounds."

Everyone agrees that no one potting material is adequate for every application but a large spectrum of applications could utilize a standardized repairable potting material. This spectrum of applications covered by the standardized potting material would include portions of all types of applications but probably in all cases it would not encompass the total application. This idea is depicted on the map on page 9. We believe that a program to standardize potting materials would save the Air Force millions of dollars per year.

SECTION II

WORKSHOP PRESENTATIONS

A. Introductory Remarks

Bill Dobbs
AFWAL/MLSS
WPAFB, OH 45433

REPAIRABLE POTTING MATERIALS WORKSHOP

NATIONAL ELECTRONIC PACKAGING AND PRODUCTION CONFERENCE

15 JUNE 1981

NEW YORK CITY COLISEUM, NY

1. "NEEDS AND REQUIREMENTS FOR STANDARDIZATION
OF POTTING COMPOUNDS"

GUS LANE
WR-ALC/MAIES
ROBINS AFB, GA 31098

2. "SM-ALC NEEDS AND REQUIREMENTS FOR POTTING COMPOUNDS"

MIKE HARRIS
SM-ALC/MAIPC
McCLELLAN AFB, CA 95652

3. "OO-ALC REQUIREMENTS FOR REPAIRABLE POTTING COMPOUNDS"

MATHEW KELAIDIS
OO-ALC/MACPA
HILL AFB, UT 84056

4. "PROBLEMS IN REPAIRABILITY OF HIGH VOLTAGE
POTTED ASSEMBLIES"

W. G. DUNBAR
BOEING AEROSPACE CO.
SEATTLE, WA 98124

5. "APPROACHES TO STANDARDIZATION IN REPAIR OF
POTTED ELECTRONIC ASSEMBLIES"

CHARLES HARPER
WESTINGHOUSE ELECTRIC CORP.
BALTIMORE, MD 21203

6. "SUPPLIER'S PHILOSOPHY OF REPAIRABILITY"
MAC LARSEN
FURANE PRODUCTS DIV.
M & T CHEMICAL
LOS ANGELES, CA 90039
7. "EMBEDMENT MATERIAL SELECTION CONSIDERATIONS
FOR REPAIRABILITY"
DALE SMITH
HUGHES AIRCRAFT CO.
FULLERTON, CA 92634
8. "REPAIRABLE POTTED HIGH VOLTAGE ASSEMBLIES"
BOB SWENDSEN
NORTHROP CORP.
ROLLING MEADOWS, IL 60008
9. "AIR FORCE RESPONSE TO SURVEY"
LT. GARY RAGSDALE
ASD/RAOF
WPAFB, OH 45433
10. "INDUSTRY RESPONSE TO POTTING COMPOUND SURVEY"
JOHN ZIEGENHAGEN
UNIVERSITY OF DAYTON RESEARCH INSTITUTE
300 COLLEGE PARK
DAYTON, OH 45469

OBJECTIVES

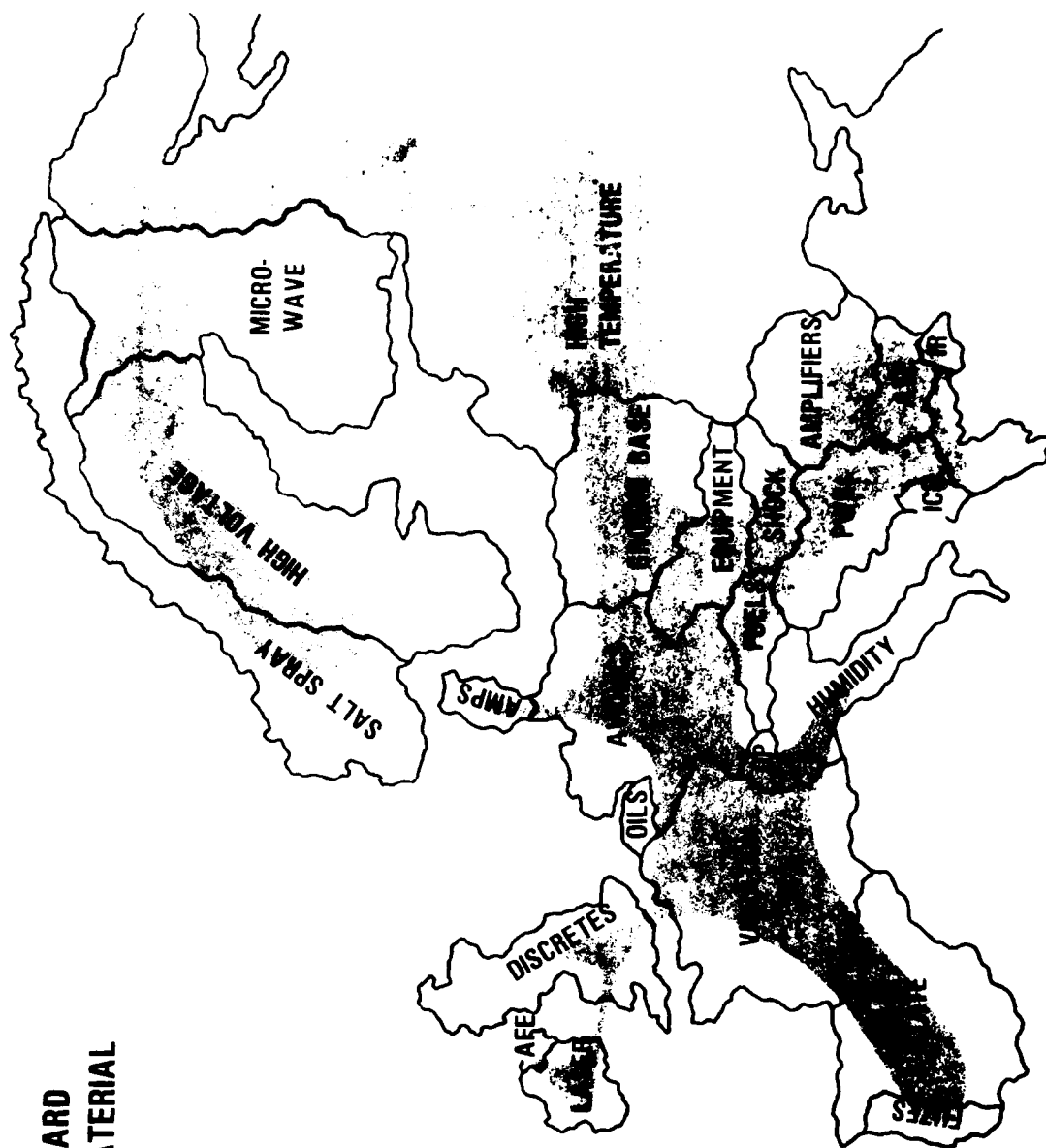
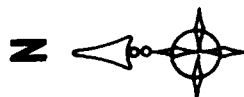
- PROVIDE INFORMATION EXCHANGE
- DISCUSS MAINTENANCE PROBLEMS
- DISCUSS REPAIR TECHNIQUES
- DISCUSS SURVEY RESULTS
- MAKE RECOMMENDATIONS ON A STANDARDIZED POTTING MATERIAL
FOR ELECTRONIC MODULES

DEFINITION

- THE TERMS

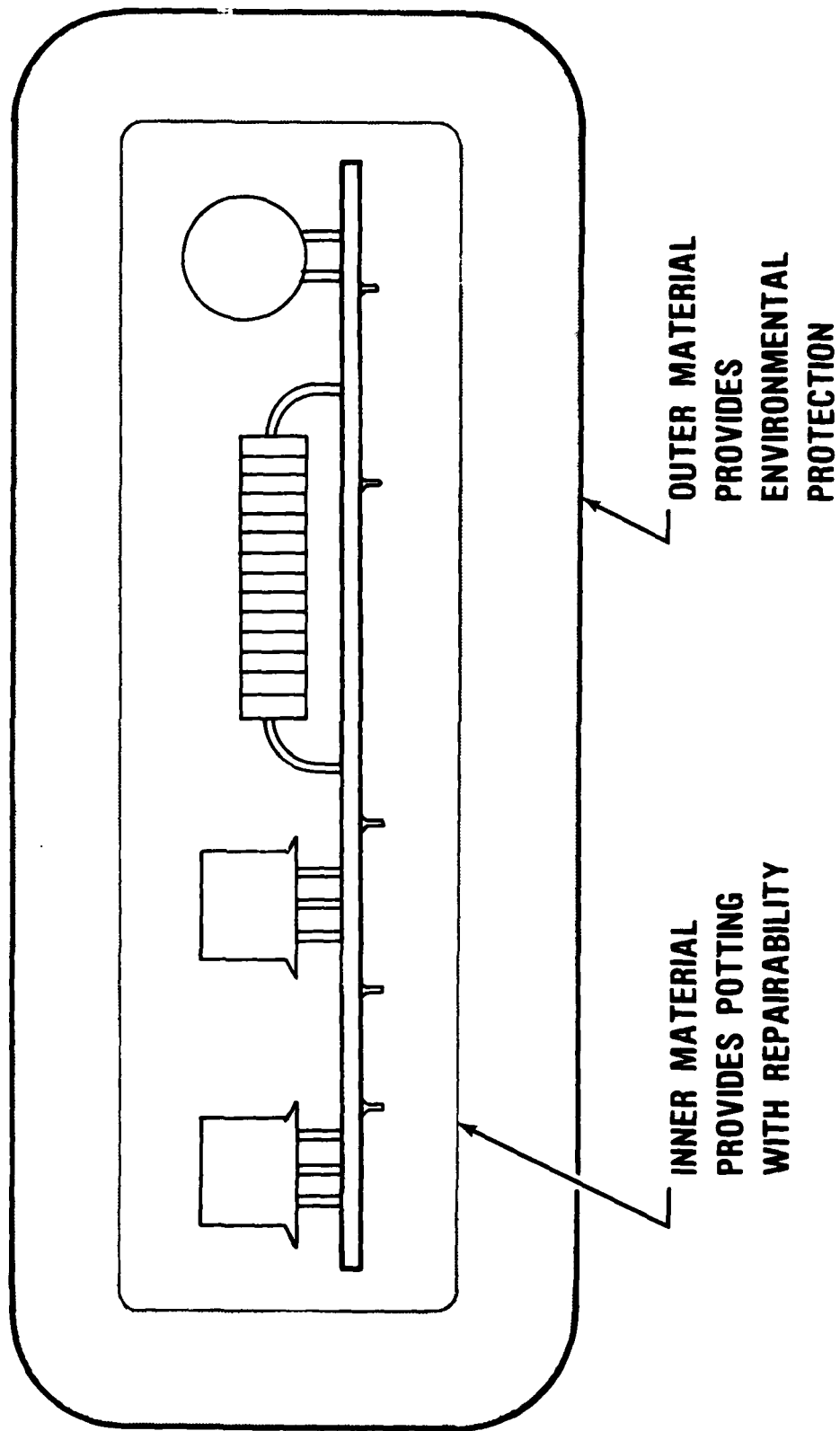
POTTING, EMBEDMENT, CASTING, ENCAPSULATION & ENCASEMENT ARE USED IN A BROAD SENSE TO INDICATE A THICK COATING OF MATERIAL OVER THE ELECTRONIC MODULE (THIS IS NOT INTENDED TO INCLUDE CONFORMAL COATINGS).

LAND OF THE STANDARD ELECTRONIC POTTING MATERIAL



TWO MATERIALS SOLUTION

- ENVIRONMENTAL REQUIREMENTS



QUESTIONS

- WHAT REMOVAL TECHNIQUES ARE AVAILABLE FOR THE DIFFERENT POTTING MATERIALS?
- WHAT DESIGN CRITERIA SHOULD BE USED FOR REPAIRABILITY?
- WHAT AREAS SHOULD BE EXCLUDED FROM REPAIRABILITY?
- WHAT POTTING MATERIALS SHOULD BE USED FOR REPAIRABLE MODULES?

B. Needs and Requirements for
Standardization of Potting Compounds

Gus Lane
WR-ALC/MAIES
Robins AFB, GA 31098

NEEDS AND REQUIREMENTS FOR STANDARDIZATION OF POTTING COMPOUNDS

ROBINS AIR FORCE BASE, GA

AVIONICS CENTER

OF THE AIR FORCE

BRIEFER: GUS LANE
WR-ALC / MAI

AIRBORNE ELECTRONICS

DIVISION

PERSONNEL	2283	
FACILITIES	480,948 SQ FT	
SYSTEMS	318	
LINE ITEMS	5,932	
EQUIPMENT	15,930	
FY-80 PRODUCTION	192,79 UNITS (\$.96 BILLION)	
FY-81 PRODUCTION	133,624 (THRU MAY)	
FY-81 BUDGET	\$122 MILLION	

MAIP BRANCH TOTAL	2,918,293	93
ATE BRANCH	<u>220,314</u>	<u>7</u>
GRAND TOTAL FOR FY-81	3,138,607	100

OUR BUSINESS—AVIONICS

FY-81 WORKLOAD PROGRAMS

SECTIONS	MANHOURS	PERCENT
ELEC WARFARE	470,860	15
BOMB-NAV	523,876	17
RADAR-NAV	433,418	14
WEAPONS CONTROL	476,441	15
FIRE CONTROL	561,680	18
COMMUNICATIONS	452,018	14

TYPICAL LIFE-CYCLE OF ELECTRONICS EQUIPMENT

- 1. DEVELOP TO SPEC**
- 2. WE PROCURE:**
 - X UNITS, WITH**
 - Y SPARES, FOR**
 - Z YEARS**
- 3. MOST EQUIPMENT EXCEEDS Z YEARS,
WITH EXHAUSTION OF Y SPARES.
MADE WORSE BY THROW-AWAY
MODULES.**

MANUFACTURING TECHNOLOGY FOR CONFORMAL COATING

FINAL REPORT: AFWAL-TR-80-4139

TWO COATINGS RECOMMENDED:

- 1. HUMISEAL 1B31 ACRYLIC**
- 2. DOW CORNING DX-X9-6326 SILICONE**

CONFORMAL

POTTING

COATINGS

COMPOUNDS

1. ACRYLICS

1. ?

2. EPOXIES

2. EPOXIES

3. PARYLENE

3. POLYSULFIDES

4. POLYURETHANES

4. POLYURETHANES

5. SILICONES

5. SILICONES

ELECTRONIC PRODUCTS

JULY 1976

SILGAN ELASTOMERS:

- 1. A NEW SYSTEM OF SEALANTS,
CONFORMAL COATINGS, AND POTTING
COMPOUNDS.**
- 2. CAN BE APPLIED BY BRUSHING, DIPPING,
SPRAYING, OR POURING**

3. QUESTION: ARE THEY SOLVENT REMOVEABLE ?

TO MEET THE MIL SPECS LET'S TRY:

- 1. SPRAY-ON COATING (THIN)**
- 2. DIP COATING (UP TO 1 / 4 IN)**
- 3. POUR OR FLOW (POTTING)**

BUT USE THE SAME REWORKABLE MATERIAL

SUMMARY

- 1. THE NEED FOR COATING AND POTTING
MIL-STD-202**
- 2. THE CONCEPT OF THROW-AWAY
MODULES IS DEPRECATED**
- 3. NEED A STANDARD COATING AND POTTING
MATERIAL THAT IS REMOVEABLE**
- 4. MOST IMPORTANT:**

MLS 12-1-2-6

SPECIFY THE STANDARD MATERIAL IN CONTRACTS

C. SM-ALC Needs and Requirements
for Potting Compounds

Mike Harris
SM-ALC/MAIPC
McClellan AFB, CA 95652

REPAIRABLE POTTED ELECTRONIC ASSEMBLIES

15 JUNE 1981

NEW YORK CITY, N. Y.

GOOD MORNING, I'M MIKE HARRIS FROM THE AIR LOGISTICS CENTER (ALC) AT
MCCLELLAN AIR FORCE BASE, SACRAMENTO, CA.

POTTED ELECTRONIC ASSEMBLIES AND SOLVENT REMOVERS HAVE BEEN AND STILL ARE MAJOR CONCERNS AND PROBLEMS AT SACRAMENTO.

BEFORE I GET INTO SOME AREAS OF CONCERN, I WILL GIVE YOU A BRIEF OVERVIEW OF HOW OUR SM-ALC, AND OTHERS, OPERATE.

SACRAMENTO AIR LOGISTICS CENTER IS A DEPOT MAINTENANCE REPAIR CENTER.

THERE ARE SIX ALC REPAIR CENTERS IN THE U.S. PLUS AIR FORCE LOGISTICS CENTER HEADQUARTERS AT WRIGHT-PATTERSON AIR FORCE BASE, DAYTON, OHIO.

ONE INTERESTING ASPECT OF THESE ALC'S IS THAT THEY ALL ARE CHARACTERIZED BY A DEGREE OF LARGENESS IN THEIR GEOGRAPHIC LOCATIONS. THREE INSTALLATIONS: OKLAHOMA CITY ALC, OKLAHOMA; OGDEN ALC, UTAH; AND WARNER ROBINS ALC, GEORGIA; ARE THE LARGEST INDUSTRIAL FACILITIES IN THEIR RESPECTIVE STATES. SACRAMENTO ALC IS THE SECOND LARGEST FACILITY IN NORTHERN CALIFORNIA AND SAN ANTONIO ALC, TEXAS IS THE LARGEST EMPLOYER IN THE SOUTHWEST.

SACRAMENTO ALC IS THE TECHNOLOGY REPAIR CENTER (TRC) FOR MANY VARIED AND COMPLEX EQUIPMENTS. EXAMPLES ARE:

HYDRAULICS, GROUND COMMUNICATIONS ELECTRONICS, SURVIVAL RADIO,
FLIGHT CONTROL INSTRUMENTS, GROUND CONTROL APPROACH RADAR ELECTRONICS
AND THEIR VANS OR SHELTERS, HONEY COMB STRUCTURES, AND F/FB 111, A-10,
F-4 AND T-39 AIRCRAFT.

AS YOU CAN SEE, MAINTENANCE IS OUR BUSINESS. OF 12,042 CIVILIAN EMPLOYEES AT MCCLELLAN, ALMOST HALF (49.5%) ARE IN MAINTENANCE.

IF YOU COMPARE THE AIR FORCE DEPOT MAINTENANCE OPERATIONS TO THE TOP 500 PRIVATE ENTERPRISES, OUR COST OF OPERATIONS, EXPRESSED IN SALES, WOULD PLACE US 164TH

IN COMPARISON TO NUMBERS OF EMPLOYEES, WE PLACE 130TH.

IN ORDER TO MAINTAIN A STATE OF READINESS, MEETING DEFENSE REQUIREMENTS, WE
EXPENDED OVER 38 MILLION MANHOURS IN 1980 REPAIRING AIRCRAFT COMPONENTS,
GROUND SUPPORT EQUIPMENT AND COMMUNICATIONS SYSTEMS.

OUR MAINTENANCE FACILITY OPERATES SIMILAR TO THAT OF A PRIVATE CONTRACTOR. WE HAVE NO OPERATING APPROPRIATIONS, (NO MONEY FROM UNCLE SAM - SO NO MONEY FROM US TAXPAYERS).

OUR CUSTOMERS HAVE APPROPRIATIONS TO PAY FOR THEIR WORKLOAD REQUIREMENTS. MAINTENANCE DEVELOPS REPAIR PRICES, FOR VARIOUS END ITEMS, AS A RESULT OF THE DEVELOPMENT OF AN OPERATING BUDGET. THIS BUDGET AND THE REPAIR PRICES REQUIRE LOCAL, COMMAND AND AIR FORCE APPROVAL.

EARNED REVENUE, THRU COMPLETION OF JOB ORDERS, IS OUR MEANS OF PAYING THE BILLS.

IN FY 80 WE SOLD \$1,406,318,782 IN SERVICES.

OUR COSTS WERE \$1,355,320,781. SO WE HAD A PROFIT OF \$50,997,947 OR 3.6% OF SALES.

OF COURSE, WE, LIKE YOU, HAVE OUR PROBLEMS WITH INFLATION.

FOR EVERY GAIN IN EFFICIENCY AND COST REDUCTION WE'VE MADE WITH IMPROVED MANAGEMENT, INCREASED PRODUCTIVITY, REPAIR SPECIALIZATION THRU IMPLEMENTATION OF UNIQUE TECHNOLOGY REPAIR CENTERS AND PLANT MODERNIZATION, THERE HAVE BEEN CONTINUING PRESSURES CAUSED BY HIGHER LABOR, MATERIAL AND UTILITY COSTS PLUS INCREASED LEAD TIME FOR PRODUCTION DUE TO LACK OF PROPER REPLACEMENT PARTS AND EXCESSIVE WORKLOAD REQUIREMENTS IN THE PRIVATE SECTOR.

OUR LABOR COSTS PER HOUR HAVE INCREASED BY 134% SINCE 1970 AND OUR MATERIAL COSTS TO OVER 110%. BUT OUR MAJOR INCREASE HAS BEEN IN UTILITIES WHERE WE'VE EXPERIENCED A 510% INCREASE.

TWO AREAS WHERE YOU, THE PRIVATE CONTRACTOR, COULD HELP SLOW THIS INFLATION RATE ARE:

1. STANDARDIZE POTTING COMPOUNDS AND SOLVENT REMOVERS.
2. SIMPLIFY IDENTIFICATION OF COMPOUNDS AND SOLVENTS, POSSIBLY BY CODING THE PART THAT IS POTTED WITH USEFUL POTTING AND SOLVENT INFORMATION.

THE MAJOR DIFFICULTY, AS I SEE IT, IS A SUITABLE SOLVENT REMOVER. AN EFFECTIVE POTTING COMPOUND REMOVER SHOULD MEET THE FOLLOWING REQUIREMENTS:

1. DISINTEGRATE OR DISSOLVE ALL THE CURED POTTING RESINS BY CHEMICAL ACTION WITHIN AN ACCEPTABLE TIME.
2. BE NON-HAZARDOUS TO THE TECHNICIAN AND THE ENVIRONMENT.
3. NOT CAUSE SWELLING OF THE POTTING MATERIAL WHICH WOULD DAMAGE PARTS.
4. NOT ATTACK OR DESTROY OTHER MATERIALS USED WITH AND AROUND THE COMPONENT BEING REPAIRED.

THIS TO ME SOUNDS LIKE A TALL ORDER, BUT, IF THESE REQUIREMENTS CAN BE MET, LABOR AND MATERIAL COSTS MAY NOT ESCALATE QUITE AS MUCH AS THEY HAVE IN THE PAST TEN YEARS.

I KNOW MANY OF THESE PROBLEMS HAVE BEEN ADDRESSED WITH NEWER WORKLOADS AND ADVANCED TECHNOLOGY, BUT HOW MUCH EFFORT HAS GONE INTO DEVELOPING METHODS OF REMOVAL FOR OLD TECHNOLOGY?

WE ARE CONCERNED WITH GETTING TO THE ROOT OF THESE PROBLEMS, WHICH TAKES US BACK TO PROFITABILITY AND LONG-TERM BUSINESS STABILITY.

THE DEFENSE PRIORITIES ACT OF 1950, DOD ESTABLISHED THE DEFENSE PRIORITIES SYSTEM (DPS). UNDER DPS WE COULD CUT, OR AT LEAST STABILIZE, COSTS AND LEAD TIME THROUGH:

1. MULTI-YEAR CONTRACTING (CAUSING HIGHER VOLUME ORDERS/SUPPORTING CAPITAL INVESTMENTS).
2. INCREASED EMPHASIS TOWARDS MATERIAL RESEARCH AND DEVELOPMENT.
3. DOD MANUFACTURING TECHNOLOGY PROGRAMS (MANTECH, ETC.), IMPROVING PRODUCTS, THEREFORE IMPROVING PRODUCTIVITY AND RESPONSIVENESS.

WHY IS IT SO IMPORTANT THAT WE HAVE REPAIRABLE POTTING COMPOUNDS AND
NON-DESTRUCTIVE SOLVENTS?

THE PRIMARY FUNCTION OF THE ALC'S IS TO PROVIDE A READY SOURCE OF TECHNICAL COMPETENCE TO SUPPORT AIR FORCE OPERATIONAL FORCES IN THE EVENT OF A GLOBAL CONFLICT AND DO IT COST-EFFECTIVELY.

WE ARE NOT ABLE TO SATISFACTORILY PERFORM THIS FUNCTION WITHOUT THE HELP OF THE PRIVATE SECTOR.

I RECALL HAVING A PROBLEM IN 1963 WITH ONE OF MY MICROWAVE TRANSMITTERS WHILE STATIONED AT MARCH FIELD NEAR RIVERSIDE, CA.

AFTER MANY HOURS OF TROUBLE-SHOOTING WE FOUND OUR PROBLEM WAS IN A 2" X 2" SEALED CONTAINER. THE TECH ORDER WIRING DIAGRAM DID NOT STATE THE CONTENTS OF THIS CONTAINER, ONLY THAT IT WAS "TOP SECRET" AND WHERE TO SEND IT TO PURCHASE A REPLACEMENT. I BROKE THE SEAL AND INSIDE WAS A STYROFOAM-TYPE POTTING MATERIAL. AFTER REMOVING THE MATERIAL, I FOUND A SMALL RESISTOR IN SERIES WITH A 12 VOLT LIGHT BULB. THE BULB HAD BURNED OUT. THIS WAS AN OBVIOUS AND DELIBERATE ATTEMPT BY A CONTRACTOR TO SELL MORE SEALED CONTAINERS.

GENTLEMEN, THIS IS NOT AN ISOLATED INCIDENT, IT NEITHER SUPPORTS OUR FUNCTION
NOR PROTECTS THE BEST INTERESTS OF THE U.S.

THE PROBLEMS AND CONCERNS I DISCUSSED THIS MORNING EXIST NOW IN OUR DEPOT MAINTENANCE FACILITIES. IT IS IMPORTANT - NO, IMPERATIVE - THAT WE REACT TO THE LIMITATIONS THAT FACE US NOW AND CONTINUE TO GIVE SERIOUS ATTENTION TO THESE SYMPTOMS AND APPLY THE NECESSARY EMPHASIS AND RESOURCES TO FIND SOLUTIONS TO OUR COMMON PROBLEMS. LIP SERVICE TO THE READINESS OF OUR COMBAT FORCES LEADS TO DISASTER.

BEING SECOND IN THIS BUSINESS

IS BEING A

LOSER

OO-ALC/Requirements For
Repairable Potting Compounds

Mathew Kelaidis
OO-ALC/MACPA
Hill AFB, UT 84056

OGDEN AIR LOGISTICS CENTER



POTTING COMPOUND PRESENTATION

WORKSHOP ON
REPAIRABLE POTTED ELECTRONIC ASSEMBLIES

15 JUNE 1981

PRESENTATION BY: MATHIEW KELAIDIS
PREPARED BY: CARLYLE JOHNSON









INTRODUCTION

GOOD MORNING, I AM MATHEW KELAIDIS FROM THE OGDEN AIR LOGISTICS CENTER'S DIRECTORATE OF MAINTENANCE AT HILL AIR FORCE BASE, UTAH. MAINTENANCE ACTIVITIES COMPRISE A MAJOR PORTION OF THE AIR FORCE LOGISTICS COMMAND'S SUPPORT EFFORTS. WE IN MAINTENANCE BELIEVE THAT ORGANIZATIONS LIKE OURS ARE THE DRIVING FORCE OF THAT LOGISTICS SUPPORT.

HERE AT OGDEN, WHICH IS THE LARGEST SINGLE EMPLOYER IN THE STATE OF UTAH WITH OVER 19,000 PEOPLE, OUR MAINTENANCE DIRECTORATE IS THE LARGEST ON-BASE ORGANIZATION WITH APPROXIMATELY 6,000 PEOPLE OR 48 PERCENT OF THE 13,000 TOTAL CIVILIAN WORKFORCE AND AN ANNUAL PAYROLL OF 145 MILLION DOLLARS. THE DIRECTORATE'S ANNUAL OPERATING BUDGET IS 242 MILLION DOLLARS WHILE OUR EQUIPMENT AND FACILITIES REPRESENT AN INVESTMENT OF ALMOST 250 MILLION.

THERE ARE 843 BUILDINGS WITHIN THE 6,600 ACRES THAT MAKE UP HILL AIR FORCE BASE: ABOUT ONE-THIRD OR 283 OF THESE BUILDINGS BELONG TO THE MAINTENANCE COMPLEX HERE AND AT THE UTAH TEST AND TRAINING RANGE ON THE WESTERN SHORE OF THE GREAT SALT LAKE.

OUR PRODUCTION EFFORTS ARE BROKEN DOWN INTO THREE MAJOR CATEGORIES: AIRCRAFT, WHERE WE ARE RESPONSIBLE FOR THE F-4, AND THE F-16; SEVERAL MISSILES WHICH INCLUDE THE MINUTEMAN, TITAN, MAVERICK, SRAM, MX, FALCON AND SIDEWINDER SYSTEMS; AND THE MANY SUBSYSTEMS ("BLACK BOXES AND INSTRUMENTS) FROM SEVERAL WEAPON SYSTEMS.

OUR FIRST PRODUCT DIVISION IS THE AIRCRAFT DIVISION. MOST OF THE AIRCRAFT WORKLOAD IS ACCOMPLISHED IN OUR 450,000 SQUARE FOOT HANGAR COMPLEX WHERE THE AIRCRAFT UNDERGO TOTAL REPAIR AND MODIFICATION.

THE MISSILE AND AIRCRAFT SYSTEMS DIVISION OVERHAULS AND MAINTAINS THE MISSILE SYSTEMS PREVIOUSLY MENTIONED AS WELL AS NAVIGATION INSTRUMENTS, PHOTOGRAPHIC UNITS AND TRAINING DEVICES. THIS IS BLDG 100 WHERE THE AIRCRAFT, MISSILES AND ASSORTED ELECTRONIC REPAIR SHOPS ARE LOCATED. THESE WORKLOADS OCCUPY EIGHT BAYS WHICH CONTAIN A TOTAL OF 181, 780 SQUARE FEET. IT IS IN THIS AREA THAT THE MAJORITY OF THE POTTING AND DEPOTTING OPERATIONS ARE ENCOUNTERED.

THIS IS BLDG 5 WHICH HOUSES THE SRAM AND MAVERICK MISSILE ELECTRONIC AND HYDRAULIC REPAIR SHOPS AND THE TRAINING DEVICES REPAIR SHOP. THESE SYSTEMS INVOLVE SOME POTTING AND ENCAPSULATION REQUIREMENTS BUT NOT TO THE EXTENT OF SOME OF THE OTHER SYSTEMS SUCH AS AIM-9 SIDEWINDER MISSILES AND AIRCRAFT.

ALL OF THESE WORKLOADS INVOLVE NUMEROUS TYPES OF ENCAPSULATION AND POTTING PROCEDURES AND PROBLEMS.

IN THIS PRESENTATION, WE WOULD LIKE TO DISCUSS BRIEFLY THE FOLLOWING POINTS WHICH ARE AN INTEGRAL PART OF THE POTTING CONCEPT AND EFFORT.

- o SYSTEM MAINTAINABILITY
- o EXCESSIVE ADDITIONAL COSTS
- o FUTURE PROCUREMENT
- o RECOMMENDATIONS

POINTS OF DISCUSSION

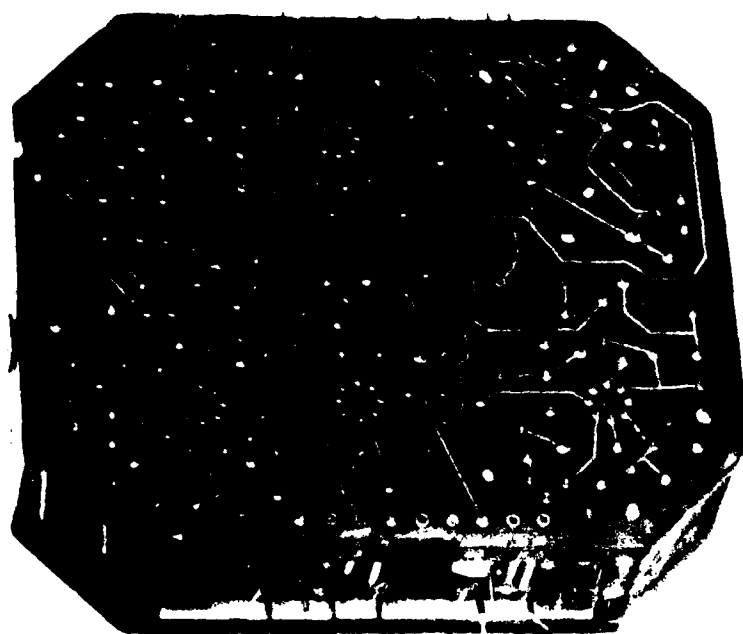
- SYSTEM MAINTAINABILITY
- EXCESSIVE ADDITIONAL COSTS
- FUTURE PROCUREMENT
- RECOMMENDATIONS

SYSTEM MAINTAINABILITY

SYSTEM MAINTAINABILITY

- NON REPAIRABLE HARD CASED POTTING
- NON AVAILABILITY OF ASSETS
- PROPRIETARY RIGHTS
- CONTROL MONITORING





SYSTEM MAINTAINABILITY

CERTAINLY WE REALIZE THAT IN MANY INSTANCES POTTING IS VERY NECESSARY TO PREVENT DAMAGE FROM VIBRATION, HEAT AND MOISTURE AND IT IS NOT OUR INTENTION TO IMPLY THAT ALL POTTING IS BAD OR UNNECESSARY. IT IS HOPED THAT THROUGH THESE WORKSHOPS AS A COMBINED EFFORT WITH THE VENDORS AND USERS WE CAN ELIMINATE SOME OF THE PROBLEMS WHICH ARE ASSOCIATED WITH POTTING AND DEPOTTING OPERATIONS.

WE ARE SEEING AN INCREASE IN POTTED MODULES ENCASED IN HARD COMPOUNDS AND SOME RUBBER AND SILICONE BASED COMPOUNDS WHICH ARE EXTREMELY DIFFICULT AND IN SOME CASES IMPOSSIBLE TO REMOVE. IN MOST OF THESE INSTANCES, AN EXPENSIVE MODULE MUST BE THROWN AWAY DUE TO THE FAILURE OF A VERY INEXPENSIVE INTERNAL COMPONENT SUCH AS A DIODE OR TRANSISTOR. THIS IS NOT ECONOMICALLY SOUND IN ITSELF AND FREQUENTLY PUTS US IN A PRECARIOUS POSITION. THAT BEING, IF AT A FUTURE DATE THE CONTRACTOR GOES OUT OF BUSINESS OR DECIDES TO DISCONTINUE PRODUCTION OF THE ITEMS, THEN WE HAVE NO WAY OF REPAIRING THE MODULES.

AS WE HAVE EXPERIENCED MANY TIMES IN THE PAST, CONTRACTORS DO NOT RESPOND TO SOLICITATIONS TO PROVIDE OUT-OF-PRODUCTION ITEMS. IF PER CHANCE SOME DO RESPOND, RETOOLING AND SMALL PRODUCTION RUNS MAKE COSTS AND LEAD TIMES ASTRONOMICAL AND OFTEN PROHIBITIVE. CONSEQUENTLY, WE ARE FORCED TO REPAIR ITEMS INTENDED FOR THROW AWAY TO MAINTAIN THE OPERATION OF THE WEAPON SYSTEM. AS YOU ARE AWARE, MANY WEAPON SYSTEMS HAVE BEEN EXTENDED CONSIDERABLY BEYOND THEIR ORIGINALLY PROJECTED LIFE. MANY OF THOSE FLYING OR REPAIRING WEAPON SYSTEMS TODAY ARE YOUNGER THAN THE WEAPONS WITH WHICH THEY ARE WORKING.

ANOTHER FACTOR WHICH HINDERS PROCUREMENT OF ALTERNATE VENDORS IS THE PROPRIETARY RIGHTS RESERVED BY THE ORIGINAL VENDOR.

THE NEW SIDEWINDER "L" CONFIGURATION HAS BEEN DESIGNED TO USE THROW AWAY MODULES. THE SYSTEM REQUIRES THREE MODULES, ONE AT AN ESTIMATED COST OF \$1200.00 AND TWO AT AN ESTIMATED COST OF \$2700.00. WHEN NEW SYSTEMS ARE BEING DESIGNED WHICH INCORPORATE NON REPAIRABLE COMPONENTS DUE TO THE USE OF HARD ENCAPSULATION, SIGNIFICANT JUSTIFICATION SHOULD BE PROVIDED TO WARRANT THE USE OF NON REPAIRABLE ITEMS.

ATTENTION SHOULD BE DIRECTED IN NEW SYSTEM DESIGN REQUIREMENTS TO LIMIT THIS IN THE FUTURE.

EXCESSIVE ADDITIONAL COSTS

POTTED COMPONENT EXPENSES

- FACILITY CHANGES
- REMOVAL SOLVENTS & CHEMICALS
- POTTING COMPOUNDS
- INCREASED LABOR STANDARDS

AIM - 9 POTTING COSTS

LABOR HOUR COST

1.5 HRS FOR REMOVAL/APPLICATION

\$15.352 HOURLY LABOR RATE

800 MISSILES REPAIRED PER QTR

COMPUTATION: $1.5 \times \$15.352 = 23,028 \times 800 = \$18,422.00 \times 4 \text{ QTRS} =$ \$73,689.60

REMOVAL SOLVENT COST

4500 GALLONS PER YEAR OF SISULFA-SOL @ \$9.00 PER GAL.

COMPUTATION: $4500 \times \$9.00 =$ 40,500.00

POTTING COMPOUND COST

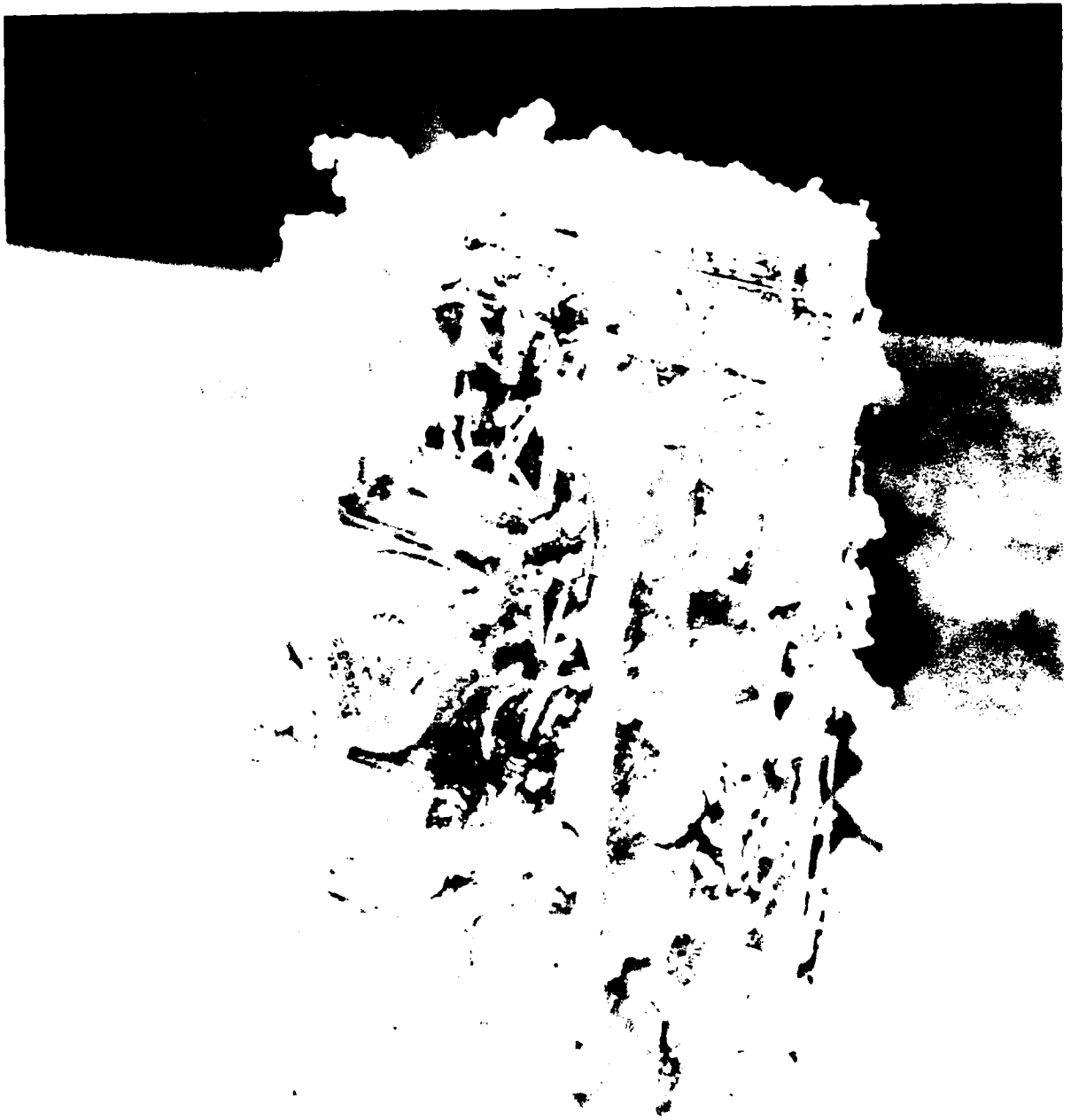
1 POTTING KIT REQUIRED PER DAY @ \$378.00

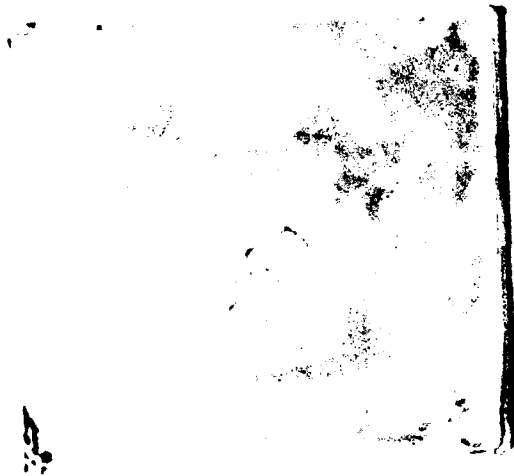
AVERAGE 20 DAY MONTH

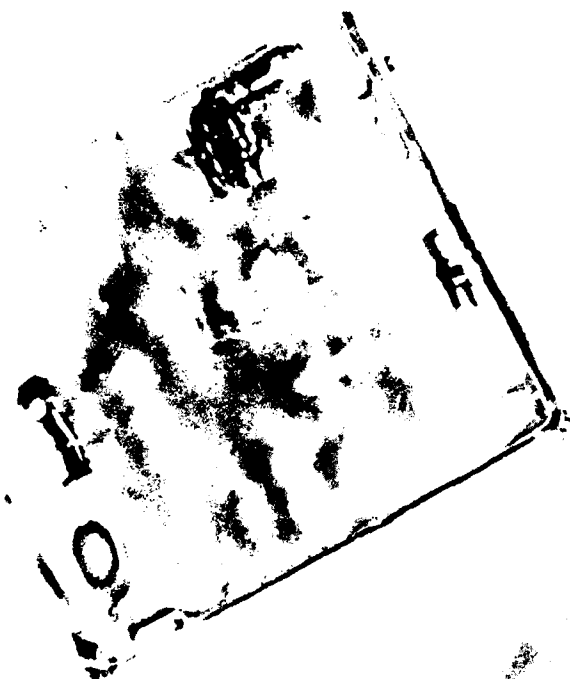
COMPUTATION: $\$378.00 \times 20 = \$7,560.00 \text{ PER MO} \times 12 =$ 90,720.00

TOTAL PER YEAR \$204,909.00

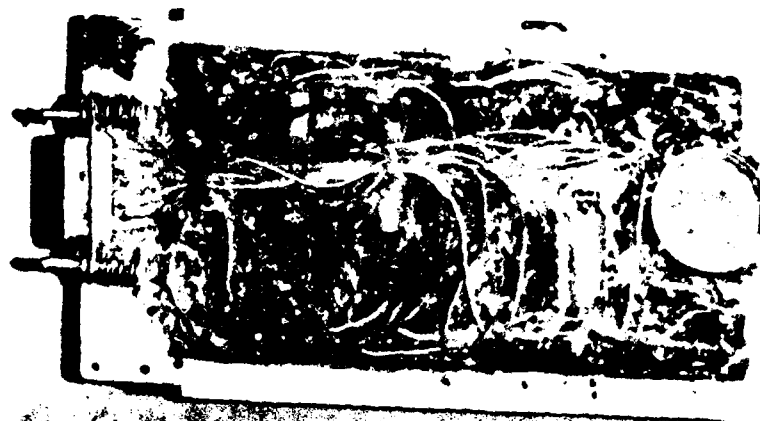
















EXCESSIVE ADDITIONAL COSTS

IT IS A WELL-KNOWN FACT THAT POTTED COMPONENTS REQUIRE MUCH MORE TIME AND EXPENSE TO REPAIR THAN NONPOTTED COMPONENTS. IN THESE DAYS OF INCREASING AUSTERITY, WE MUST DILLIGENTLY SEEK WAYS TO DECREASE REPAIR COSTS. AS AN EXAMPLE OF HOW MUCH MONEY IS INVOLVED IN POTTED COMPONENT REPAIR COMPARED WITH NONPOTTED COMPONENTS, WE WOULD LIKE TO PRESENT THE FOLLOWING INFORMATION FOR CONSIDERATION.

THESE FIGURES APPLY TO THE POTTING AND DEPOTTING COSTS CONCERNING REPAIR/OVERHAUL OF THE AIM-9 SIDEWINDER MISSILE REPAIRED AT OGDEN ALC.

IT CAN BE SEEN FROM THESE FIGURES HOW EXPENSIVE IT IS TO DEAL WITH POTTED COMPONENTS. IN THIS ONE REPAIR AREA, IT COSTS ALMOST A QUARTER MILLION DOLLARS PER DAY FOR REMOVAL AND APPLICATION OF THE POTTING. THESE FIGURES DO NOT INCLUDE THE COST OF THE FACILITY AND SPECIAL EQUIPMENT WHICH WOULD MAKE THE COST CONSIDERABLY HIGHER.

IN MOST CASES WHEN POTTED COMPONENTS ARE WORKED, IT INDUCES ADDITIONAL COST FOR FACILITY CHANGES, REMOVAL CHEMICALS AND SOLVENTS, POTTING COMPOUNDS AND INCREASED LABOR STANDARDS.

THESE ARE ALSO THE HIDDEN COSTS OF SHIPPING, STORAGE AND HANDLING OF THE CHEMICALS AND COMPOUNDS WHICH ADD TO END ITEM REPAIR COSTS.

THIS EXAMPLE I HAVE PRESENTED IS ONLY ONE OF HUNDREDS OF ITEMS WHICH INVOLVE SIMILAR POTTING PROBLEMS SO IT IS EVIDENT THAT MILLIONS OF DOLLARS PER YEAR ARE SPENT ON THE POTTING EFFORT. WHENEVER POTTED COMPONENTS ARE USED, SUFFICIENT BENEFITS SUCH AS REDUCED FAILURE RATE, EXTENDED OPERATING LIFE AND IMPROVED PERFORMANCE SHOULD BE OBTAINED TO PROVIDE A SAVINGS TO OFFSET HIGHER PROCUREMENT COST.

A CONCERTED EFFORT SHOULD BE MADE TO RESTRICT USE OF HARD POTTING COMPOUND TO JUSTIFIED APPLICATIONS.

FUTURE PROCUREMENT

PROCUREMENT IN THE FUTURE

- RESTRICTION OF CERTAIN TYPES OF MATERIALS.
- MANUFACTURERS PROVIDE REMOVAL METHODS & MATERIALS REQUIRED.
- POTTING BE USED ONLY WHEN ABSOLUTELY NECESSARY.
- UTILIZATION OF ENVIRONMENTAL CONNECTORS.

FUTURE PROCUREMENT

THERE IS VERY LITTLE THAT CAN BE DONE WITH THE ITEMS WHICH ARE ALREADY IN EXISTENCE AND BEING REPAIRED AT THE PRESENT BUT THE "LESSONS LEARNED" NOW SHOULD INFLUENCE GREATLY WHAT HAPPENS IN THE FUTURE.

SOME OF THE THINGS WHICH WE FEEL SHOULD BE CONSIDERED ARE AS FOLLOWS:

1. CERTAIN MATERIALS WHICH ARE DIFFICULT OR IMPOSSIBLE TO REMOVE SHOULD BE RESTRICTED FROM USE UNLESS IT IS DETERMINED TO BE ABSOLUTELY NECESSARY AND UNAVOIDABLE.
2. WHEN POTTED ITEMS ARE PROCURED THE MANUFACTURER SHOULD PROVIDE A REMOVAL METHOD AND IDENTIFY MATERIALS REQUIRED SO THAT INDIVIDUAL REPAIR SHOPS WILL NOT REQUIRE SPECIAL ASSISTANCE FROM THEIR CHEMICAL LABORATORY PEOPLE.
3. AS WAS INDICATED PREVIOUSLY, A CONCERTED EFFORT SHOULD BE MADE TO ELIMINATE ALL POTTING THAT IS NOT ABSOLUTELY ESSENTIAL.
4. INCREASED EFFORT SHOULD BE MADE TO UTILIZE ENVIRONMENTAL CONNECTORS ON AIRCRAFT AND MISSILE SYSTEMS RATHER THAN POTTED CONNECTORS.

RECOMMENDATIONS

RECOMMENDATIONS

- o WE STRONGLY RECOMMEND STANDARDIZATION OF POTTING MATERIALS WHICH SHOULD SIGNIFICANTLY DECREASE POTTING AND DEPOTTING COSTS AND ELIMINATE MUCH OF THE CONFUSION OF ORDERING, DISTRIBUTION, HANDLING AND USE WHICH AFFLICTS US NOW.
- o WE FEEL THAT CHEMICAL REMOVAL METHODS ARE MORE ADVANTAGEOUS FOR OUR REQUIREMENTS THAN WOULD BE MECHANICAL REMOVAL.
- o COMPOUNDS SHOULD BE OF A TYPE THAT DO NOT REQUIRE HARSH OR ABUSIVE SOLVENTS THAT DAMAGE COMPONENTS, WIRING OR PRINTED CIRCUIT RUNS.
- o POTTING COMPOUNDS SHOULD BE OF A TYPE THAT IS EASILY AND QUICKLY REMOVED.
- o COMPOUNDS SHOULD BE EASILY APPLIED AND CURE TIME SHOULD BE RELATIVELY FAST.
- o COMPOUNDS SHOULD BE TRANSPARENT TO ALLOW PRE-TEARDOWN INSPECTION BEFORE STRIPPING.
- o AS WAS MENTIONED BEFORE WE ALSO FEEL THAT SOME TYPE OF ENFORCEMENT SHOULD BE IMPLEMENTED TO ELIMINATE UNNECESSARY POTTING.
- o OTHER METHODS SUCH AS VACUUM PACKING COULD BE CONSIDERED RATHER THAN POTTING.

R E C O M M E N D A T I O N S

- o STRONGLY RECOMMEND STANDARDIZATION.
- o CHEMICAL REMOVAL OF POTTING BE USED.
- o SHOULD NOT REQUIRE HARSH OR ABRASIVE CHEMICALS.
- o COMPOUNDS BE EASILY & QUICKLY REMOVED.
- o COMPOUNDS SHOULD BE EASILY APPLIED.
- o CURE TIME SHOULD BE FAST.
- o SHOULD BE TRANSPARENT.
- o ELIMINATE UNNECESSARY POTTING.
- o ALTERNATE METHODS TO POTTING SHOULD BE DEVELOPED.

E. Problems in Repairability of
High Voltage Potted Assemblies

W. G. Dunbar
Boeing Aerospace Co.
Seattle, WA 98124

PROBLEMS AND GUIDELINES
FOR REPAIRABILITY OF
POTTED HV POWER SUPPLIES

W. G. DUNBAR
JUNE 15, 1981

BOEING AEROSPACE COMPANY

THE **BOEING** COMPANY
SEATTLE, WASHINGTON

PROBLEM AREAS AND SUGGESTED SOLUTIONS

High-voltage systems are plagued with annoyances that are unnoticed in low-voltage systems. Some of the more subtle annoyances are described in the following paragraphs:

Debris. Small dielectric flakes or chips lodged or lying on the surface or edge of a coil will align themselves with the electric field. They will be charged to the same potential as the surface to which they are attached, acting as a point on the surface. This will decrease the utilization factor of the encapsulating gas or oil and cause excessive corona and eventual breakdown. Inspections and thorough cleaning with high-pressure air will eliminate this problem.

Small pieces of insulation must be cleaned out of transformer cases, otherwise "chips" may lodge in the field between a coil and metal and cause corona, which ruins the gas or oil insulation. Wire terminations should be designed and installed so that the field approaches that of a parallel-plate configuration without point discontinuities.

Mechanical Stress. Sharp edges or points on fasteners, connections, and rivets can cause insulation boards to chip or crack. Terminations should be designed to minimize mechanical stress points on the insulating boards. This can be accomplished by molding the terminal in a solid insulating material that is attached to the board. The metal spacers not only reduce the mechanical stress but also increase the surface utilization factor between the flange edges.

Flexible Wiring. Flexible wiring is easily misaligned during the potting process, causing high voltage wires to be overstressed during operation. High-voltage, extra-flexible wiring is acceptable in some limited cases. It should be used only as a last resort. When used, it should be guided from terminal to terminal to eliminate the probability of the wire insulation intermittently touching other surfaces containing higher or lower voltage circuits.

Manufacturing Cleanliness. The need for manufacturing cleanliness cannot be overstressed. Gloved hands should be mandatory when papers, films, and other cleaned surfaces are handled. Small amounts of oils or acids can cause an improper bond or encapsulation. Any paper, cloth, film, or other dielectric material is suspect and should be inspected by materiel, shop fabrication, and engineering personnel. Smoke-emitting objects in materials fabrication shops may contaminate the dielectric.

Mold Release Agents. Silicone products may contaminate certain epoxies, urethanes, and other insulating materials. Compatibility and contamination of materials for bonding purposes should be investigated prior to fabrication. When there is an incompatibility, precautions must be taken to avoid contamination.

Testing. Flaws in outer surfaces or between a single conductor and a surface in a clear material can be visually inspected. When a coil, circuit, or multiple-conductor assembly is tested, the test must include the detection of imperfections between coil layers, circuit parts, and assembly layers. This implies that the total assembly must be energized in such a way that all overstressed electrical parts will be detected. An overvoltage test and/or overfrequency test are two methods for testing.

Environment and Life. Most high-voltage circuits and parts will be installed in enclosed pressurized containers. This reduces the probability of thermal shock, but not temperature extremes. Testing an insulation in a small dish is inadequate. Fabricated parts and circuits should be assembled (per specification) inside the packaging container and tested through the temperature extremes with all circuits energized. Five to nine cycles are recommended. Pre-environmental tests and post-environmental tests should include corona, dissipation factor, insulation resistance, and a visual inspection of breaks, tears, and deformation. Any significant change in appearance or electrical characteristics are reasons for further testing and/or modification prior to qualification and life testing.

Tabs. Small tabs often are placed on wires and parts for identification and installation purposes. When these coils and circuits are encapsulated, film-tape tabs such as Mylar adhesive may cause built-in gas pockets or voids. These voids may initiate partial discharges and eventual voltage breakdown. If tabs are required, they should be made of porous materials that are compatible with and easily wetted by the encapsulant.

Spacers. Spacers between the two energized encapsulated units must be nearly void-free and have smooth or rounded surfaces to reduce tracking susceptibility across the spacer surface. The spacer surface should be designed as though the voltage at the dielectric surfaces was from base electrodes, not dielectrics.

Coatings. Coated metal surfaces have higher breakdown voltage characteristics than uncoated surfaces, provided the correct coating material is applied. Some coatings do not blend well, flake, and reduce the electrical stress capability of

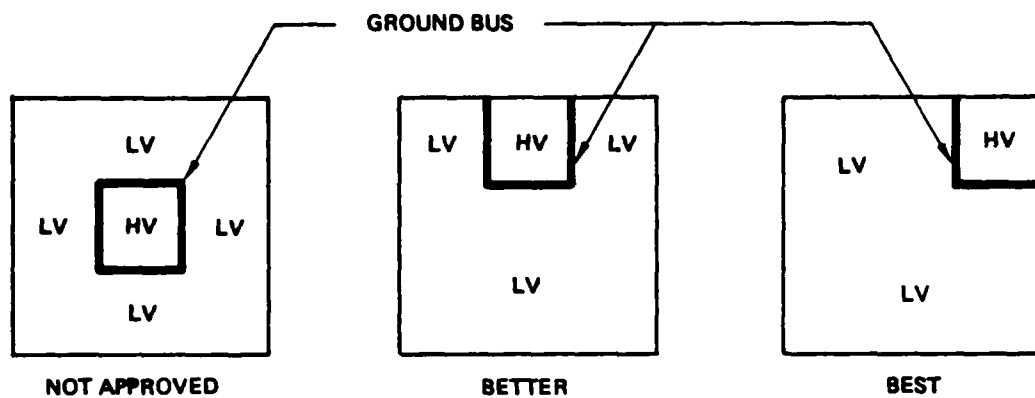


Figure 1. Common Boundary, HV and LV Circuits

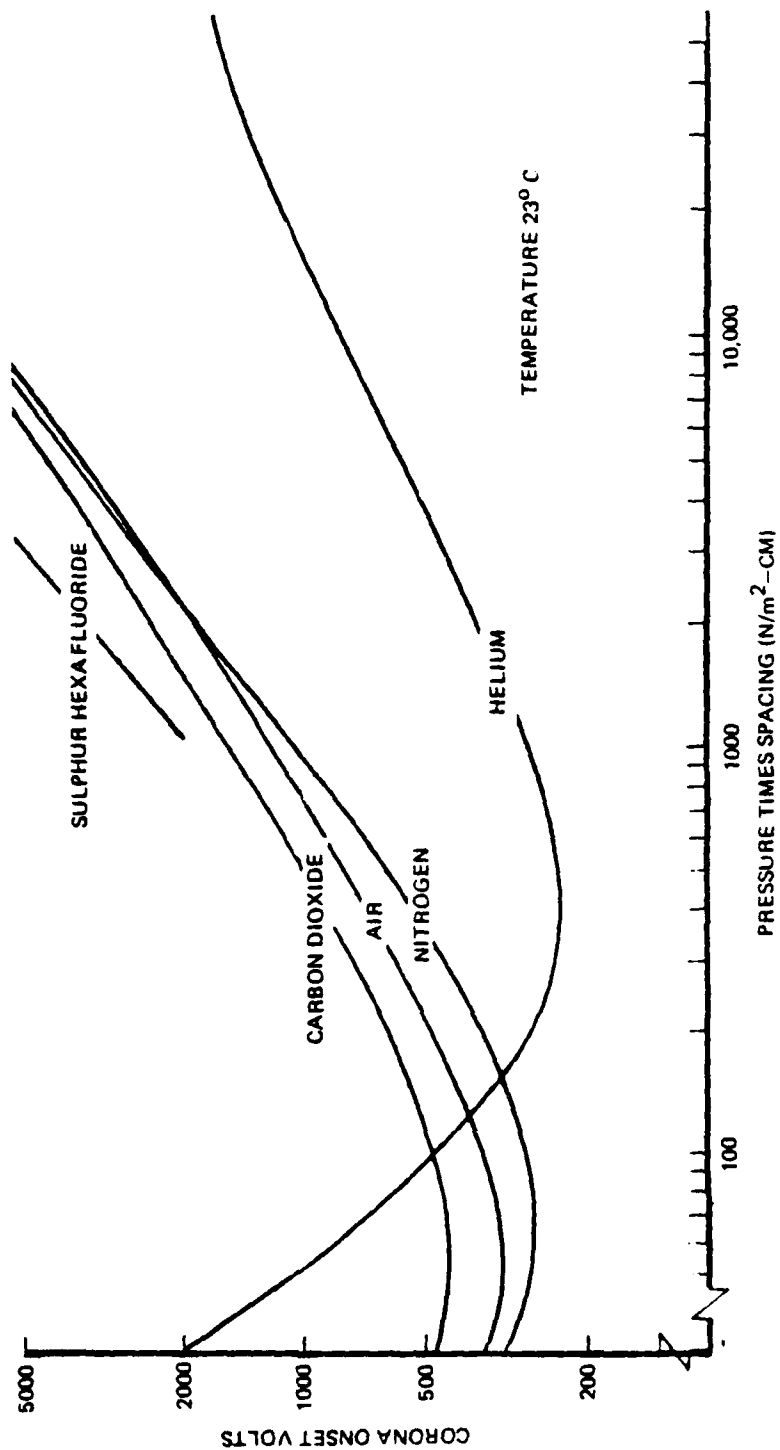


Figure 2. Direct Current Breakdown Voltage Between Parallel Plates

the two electrodes. Others may have pin holes and voids or blisters that also cause flaking. Coatings must be evaluated under identical environmental and electrical stress conditions to be fully qualified.

Determining Corona Limitation Voltage. The corona initiation voltage (CIV) of an electrical apparatus can be determined when the design parameters and the applicable Paschen-law curve are known. The Paschen curve used depends on the type of gas in which the corona would occur, the temperature of the gas, and the configuration of the electrodes. Figure 2 compares Paschen curves for different gases under d.c. voltage. The most common gas is air. If the temperature exceeds 260°C, special Paschen curves must be used.

DESIGN IDEAS THAT HAVE WORKED IN HIGH-VOLTAGE EQUIPMENT

Examples of successful designs used to decrease field stress in high-voltage equipment are described in the following paragraphs:

Terminal Boards and Supports. Composite and laminated insulation is used for terminal boards and for supports that separate the coils and wiring from the cores, structure, and containers. A terminal board for high potential should be made from qualified insulation. The board may be flat, if the voltage is less than 20 kV, provided the electrical stress is:

- o Less than 20 V/mil for long life (10 to 30 years)
- o Less than 20 to 50 V/mil for short life (1 month to 1 year)

With treated boards in a dry, clean atmosphere of pure gas, these values can be doubled.

Terminal boards operating at voltages greater than 20 kV should be contoured to increase the creepage paths. Three basic methods of contouring (shown in fig. 3) are:

- o Cutting slots (gas-filled regions) between the terminals
- o Building barrier strips between the terminals
- o Mounting the terminals on insulated standoffs

Combinations of the three methods may be necessary for voltages greater than 100 kV.

The slots in a slotted circuit board form creepage paths as well as flashover barriers on both sides of the board. A board with barriers is the most difficult to design. The barriers must be built on both sides of the board, and the board has to be made from materials that will not form creepage paths under the barriers, inside laminated boards, or through the board laminates. The barriers also must not interfere with the terminals or the wiring.

Insulated standoffs are a form of barrier strips. The standoffs are difficult to design because they must withstand the forces applied by the terminals, and the terminal anchor must be embedded in the top surface of the standoff. The anchor must be contoured for minimum electrical stress.

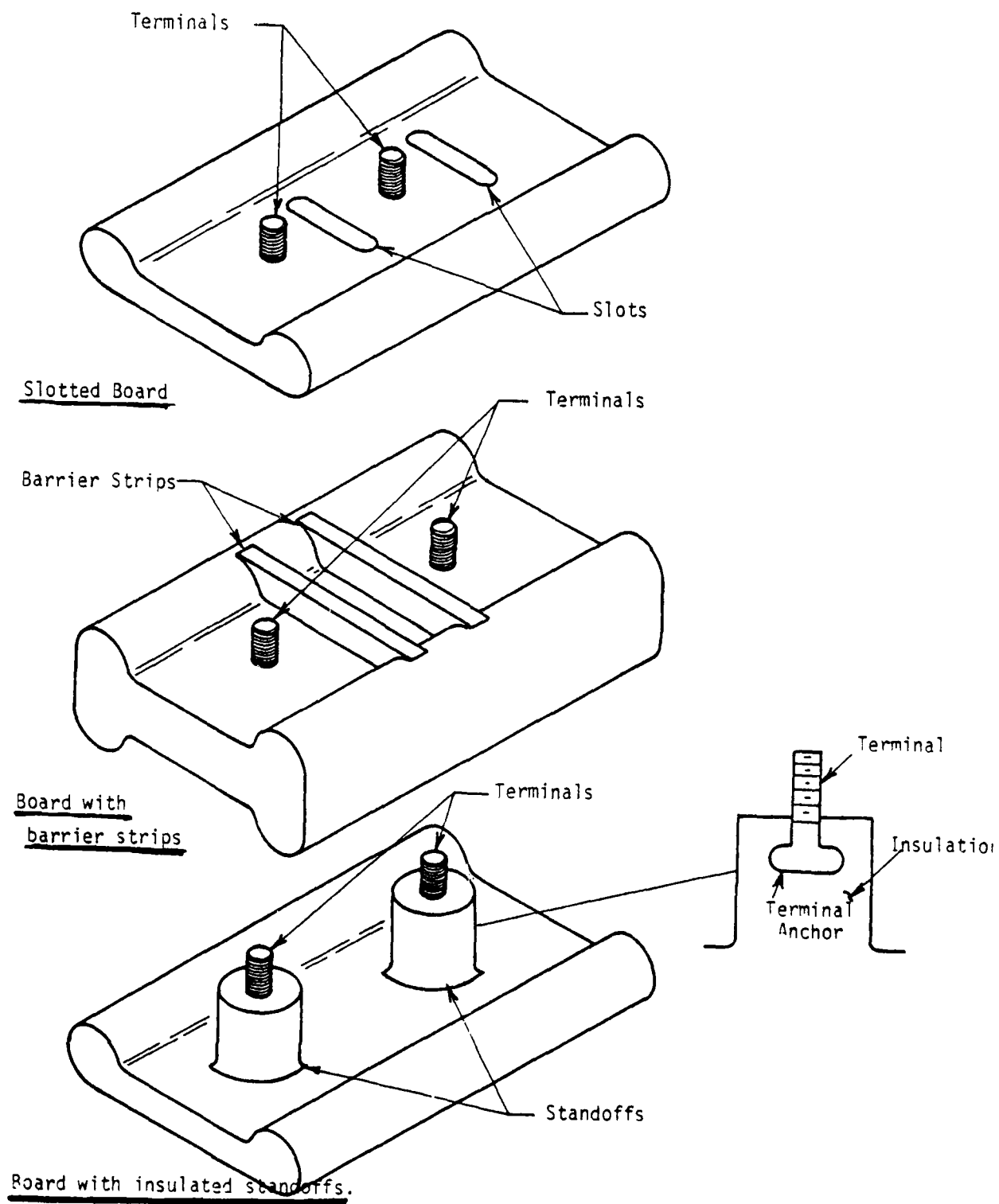


Figure 3. Terminal Boards

High-Voltage Leads. Leads between high-voltage parts should be made of round, smooth-surfaced, polished metal tubing. Steel and nickel-plated metals are preferred, but softer metals often are used because they are easier to fabricate. The radius of curvature on all bends should be at least 2.5 times the conductor diameter to avoid flattening or crushing the tube at the bend. The ends of the tubes should be flattened as little as possible, but this becomes difficult for pieces other than straight sections. When the end of the tubing is flattened, the corona-suppression shield should extend over the edges and the flattened end of the tubing, as shown in figure 4. Ample space must be provided between the inside surface of the insulator and the metal tube. A safe design would be based on the assumption that the full voltage stress exists on the top edge of the bushing.

Hollow tubing must be vented. Vent holes should be drilled through one wall of the tubing at both ends. The vent hole should face the corona shield.

Special Design Features. High-voltage, flexible-lead terminations should be designed to eliminate pressure points on the terminal board (fig. 5); pressure points will cause delamination, which enhances internal tracking. The terminal should be protected with a corona ball or shield.

Other insulation techniques include either burnishing or enameling over the knots in ties to prevent the feathered ends from becoming points from which corona discharges will emanate (fig 6).

Standoffs and Boards. For high-density packaging, high-voltage parts are separated by either laying them out on the surface of a board or placing them on

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AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/G 5/1
AIR FORCE/INDUSTRY REPAIRABLE POTTING MATERIALS WORKSHOP, (U)

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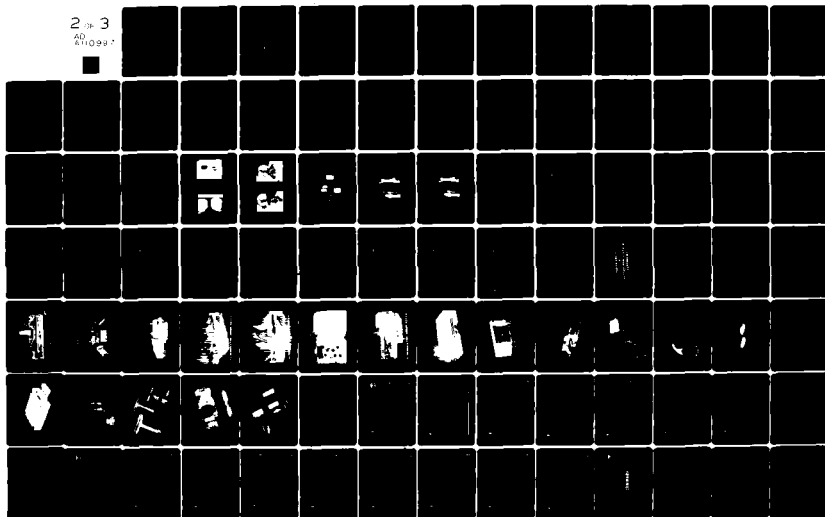
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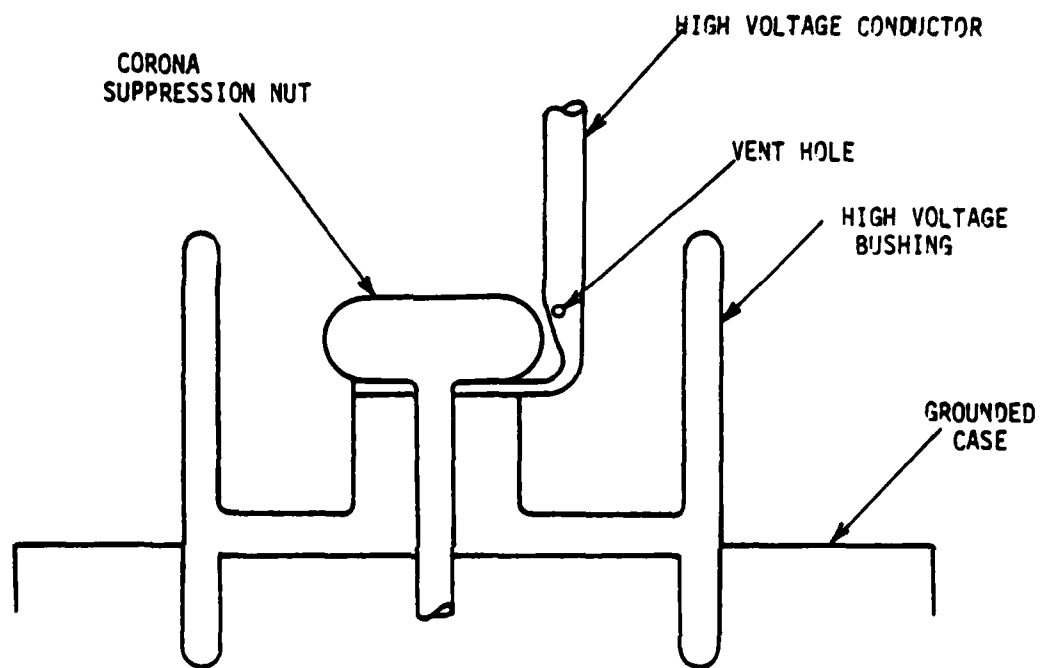
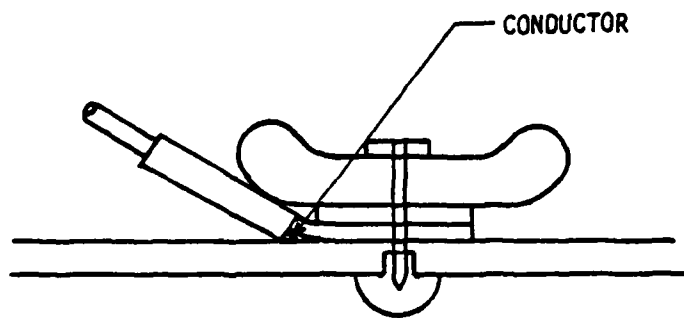
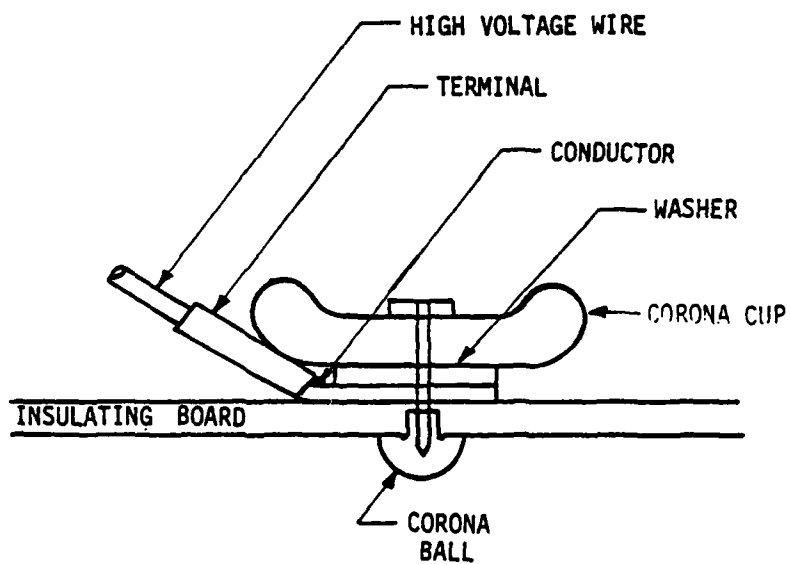


Figure 4. High Voltage Lead and Bushing



IMPROPER



PROPER

Figure 5. High Voltage Terminals

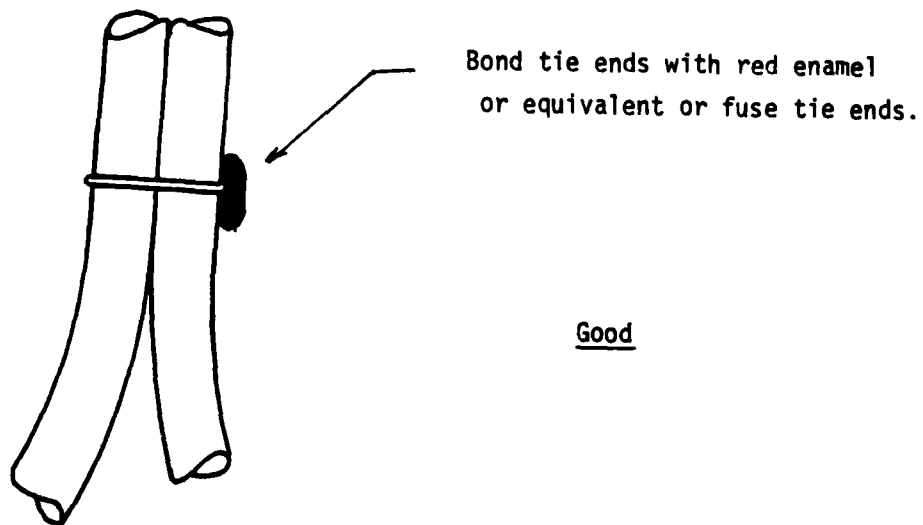
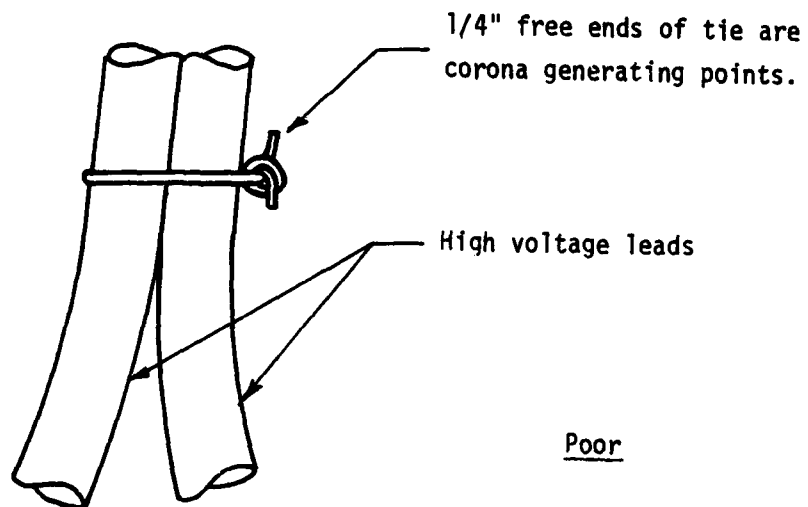


Figure 6. High Voltage Ties

standoffs. A few critical problem areas on board delamination, joints, cleanliness, surface coating, and edges.

Board Delamination. Boards used to separate high-voltage parts from grounds must serve a dual purpose: structural and mechanical. Fiberglass usually is used as the major composition of boards, with epoxy or other material used for the filler. When the board is made in large, thick sections, the filler material occasionally does not completely penetrate the fiber. This will cause the board to have large internal voids that are difficult to detect.

Once a board is found with this type of fault, it is best to have all boards scanned for defects, otherwise application of a high potential will initiate internal tracking and failure. These types of failures usually are discovered in the field after many hours of service.

Joints. Screws frequently are used to join a metal plate to the end of a rod or standoff. This is strictly unacceptable in high-voltage designs because the screw hole is deeper than the screw; thus, a void exists at the bottom of the screw hole and the screw will attain a potential causing a very high field gradient at the point of the screw and along the threads. This will cause a high-voltage gradient across the air gap. Then partial discharges will enhance treeing through the standoff, resulting in arcing. Banding with a loose-fitting clamp is best. A tight-fitting clamp should not be used because if the clamp is tightened enough to secure the standoff in place, it will cause the standoff to delaminate, and tracking will occur (see fig. 7).

Cleanliness and Surface Coatings. Prior to coating the surface of a board or joint, before or after assembly, the surface must be thoroughly cleaned of oils,

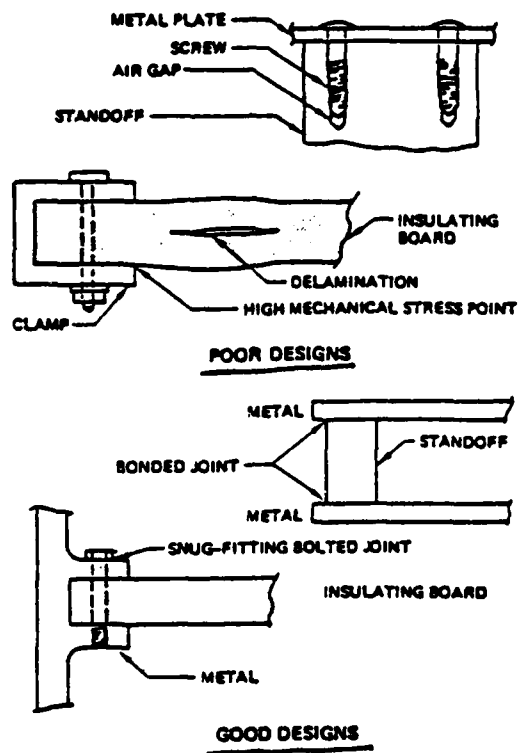


Figure 7. Board Standoff Clamping

greases, dirt, foreign objects, cleaning salts, and acid deposits. Large boards often require two or more cleaning processes . Following cleaning, the board should be taken to the area where the coating is applied. During transportation the board should not be touched with bare hands or contaminated objects, nor exposed to a contaminating atmosphere. The coating must be placed on the board in a dust-free/lint-free compartment. Likewise, during installation into the final assembly, the board must be handled so as not to contaminate the surface.

Edges. A large board often has cutouts, holes, slots, and indentations. Remember, all edges are to be smoothed and rounded. A sharp edge on an insulating board has the same effect as a sharp edge on a metal sheet.

Taps and Plates. A high-voltage rectifier normally is assembled from a series of connected diodes, and occasionally, a voltage tap is required at the center of the diode string. This tap should be made of material having the same diameter as the diode surface and thick enough for attachment of a round tubular connection. Soldered joints should not be used because most solder electrodes have lower breakdown potentials than metals such as steel, nickel, brass, copper, and aluminum.

A potential shaping surface within the stack of series-connected diodes can be a thin plate of metal provided with a large-radius edge. This curved edge suppresses corona.

GUIDELINES TO MINIMIZE FAILURES

LAYOUT TO MINIMIZE AVERAGE VOLTAGE STRESS

DESIGN TO PROVIDE ADEQUATE SPACING

- a) USE CREEPAGE BARRIERS
- b) INCREASE PACKAGE SIZE IF NECESSARY
- c) SELECT HIGHER STRENGTH DIELECTRIC

RESTRAIN ROUTED WIRES TO PREVENT MOVEMENT DURING POTTING

PARTS AND MATERIALS SELECTION TO MINIMIZE VOLTAGE STRESS INTENSIFICATION

- a) SOLDER BALLS
- b) SELECT HARDWARE TO AVOID EXPOSED SHARP EDGES
- c) USE VOLTAGE SHIELDS
- d) USE LARGE DIAMETER SMOOTH CONDUCTORS
- e) SELECT INSULATION WITH COMPATIBLE DIELECTRIC STRENGTH (AC)
- f) SELECT INSULATION WITH COMPATIBLE RESISTIVITY (DC)

GUIDELINES TO MINIMIZE FAILURES (CONTINUED)

DESIGN TO LIMIT MODULE TEMPERATURE RISE

- a) USE RELIABILITY (DERATING) CRITERIA TO DETERMINE ACCEPTABLE COMPONENT TEMPERATURES.
- b) LAYOUT TO MINIMIZE THERMAL PATH FROM HEAT SOURCES TO HEAT SINK.
- c) CONSIDER USE OF "LOADER" (HIGHER CONDUCTIVITY) INSULATING MATERIAL.
- d) CONSIDER USE OF METAL OR CERAMIC THERMAL SPREADERS.
- e) CONSIDER USE OF FINS OR INTERFACE MATERIAL TO REDUCE THERMAL RESISTANCE FOR MODULE TO AMBIENT.
- f) IF NECESSARY INCREASE PACKAGE SIZE.
- g) SELECT THERMALLY STABLE MATERIALS

DESIGN TO MINIMIZE NUMBER AND SIZE OF VOIDS IN INSULATION

- a) PACKAGING GEOMETRY TO ALLOW "EASY FILL" AND GAS ESCAPE.
- b) DESIGN PACKAGE TO ACCOMMODATE CURE SHRINKAGE.
- c) SELECT LOW VISCOSITY, LONG POT LIFE MATERIAL.

GUIDELINES TO MINIMIZE FAILURES (CONTINUED)

DESIGN TO PREVENT INSULATING MATERIAL CRACKS AND DELAMINATION, AND PART OR SOLDER JOINT FAILURE, DURING THERMAL CYCLING.

- a) PACKAGING CONFIGURATION TO ACCOMMODATE INSULATION SHRINKAGE AND EXPANSION (PHYSICAL CONSTRAINTS).
- b) MAXIMIZE COEFFICIENT OF EXPANSION COMPATIBILITY.
- c) MAXIMIZE MATERIAL COMPATIBILITY TO PROMOTE ADHESION.
- d) SELECT LOW BULK MODULUS INSULATION IF MATERIAL IS SEVERELY CONSTRAINED.
- e) COMPONENT MOUNTING TO PROVIDE STRESS RELIEF.
- f) IF NECESSARY SOFT CONFORMAL COATING OF SENSITIVE COMPONENTS.

DESIGN TO MINIMIZE PARTICULATE CONTAMINATION

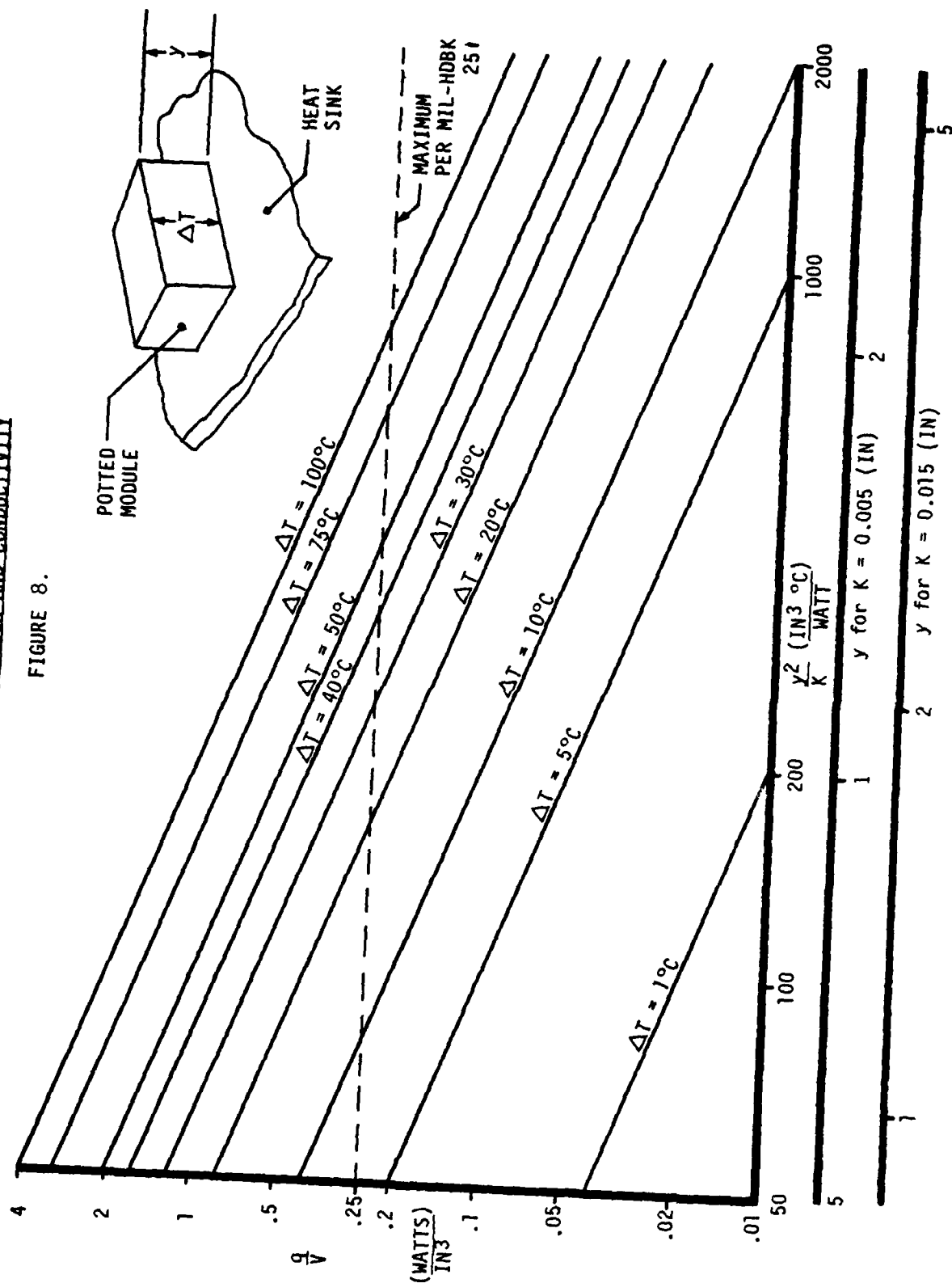
- a) PACKAGING DESIGN TO ALLOW EASY CLEANING (NO "PARTICLE TRAPS").

DESIGN TO MINIMIZE UNDESIRABLE CIRCUIT INTERACTION (COUPLING)

- a) LAYOUT TO SEPARATE LOW NOISE SENSITIVE CIRCUITS FROM NOISY CIRCUITS.
- b) IF NECESSARY USE SHIELDING.

CONDUCTION COOLED MODULE TEMPERATURE RISE
UNIFORM DISSIPATION AND CONDUCTIVITY

FIGURE 8.



F. Approaches to Standardization in
Repair of Potted Electronic Assemblies

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Westinghouse Electric Corp.
Baltimore, MD 21203

ROLES OF STANDARDIZATION OF REPAIR OF POTTED ASSEMBLIES

- STANDARDIZATION IN DESIGN AND APPLICATION
- STANDARDIZATION IN MATERIALS PERFORMANCE REQUIREMENTS
- STANDARDIZATION FOR MATERIALS REPAIR TECHNIQUES

STANDARDIZATION IN DESIGN AND APPLICATION

- FUNCTIONAL PARTITIONING (ELECTRICAL REQUIREMENTS, OTHER REQUIREMENTS)
- APPLICATION PARTITIONING (COST, MANUFACTURABILITY, ETC.)
- CRITICAL COMPONENT PARTITIONING
- THROW-AWAY VS. NON-THROW-AWAY CONSIDERATIONS

STANDARDIZATION IN MATERIALS PERFORMANCE REQUIREMENTS

- LOW VOLTAGE, REPAIRABLE
- LOW VOLTAGE, NON-REPAIRABLE
- HIGH VOLTAGE, REPAIRABLE
- HIGH VOLTAGE, NON-REPAIRABLE
- LOW LOSS, REPAIRABLE
- LOW LOSS, NON-REPAIRABLE
- OTHER PERFORMANCE REQUIREMENTS

STANDARDIZATION OF MATERIALS REPAIR TECHNIQUES

- STANDARD IDENTIFICATION TECHNIQUES
- STANDARD CHEMICAL STRIPPING
- STANDARD MECHANICAL REPAIR

TABLE I
QUANTITATIVE REQUIREMENTS FOR QUALIFICATION TESTS

<u>Property</u>	<u>Units</u>	<u>Method Paragraph</u>	<u>ASTM or Fed-Std-406</u>	<u>Value</u>
Specific Gravity (1)		4.6.2	5011	(2)
Dielectric Strength, 1/8 inch	Volts/Mil (Min)	4.6.3	4031	465-485
Dielectric Constant			4021	
Type I at 10 ³ Hz	Maximum			5.0
Type II at 10 ³ Hz	Maximum			4.6
Dissipation Factor			4021	
Type I at 10 ³ Hz	Maximum			.003
Type II at 10 ³ Hz	Maximum			.004
Hydrolytic Stability				
Volume Resistivity	ohm-cm	4.6.5	4041	
Type I Before Conditioning	Minimum			1 x 10 ¹⁴
Type II Before Conditioning	Minimum			1 x 10 ¹⁵
Hardness		4.6.5	ASTM D2240	
As Received	Minimum			45
Type I				75
Type II				10% Reduction from initial value for individual products
After Conditioning	Maximum			
Type I				
Type II				
Arc and Track Resistance	Seconds	4.6.6	4011 ASTM D495	
Type I	Minimum			190
Type II	Minimum			190

TABLE I (Continued)

<u>Property</u>	<u>Units</u>	<u>Method Paragraph</u>	<u>ASTM or Fed-Std-406</u>	<u>Value</u>
Thermal Expansion	cm/cm/°C	4.6.7	2031	
Type I	Maximum			280×10^{-6}
Type II	Maximum			70×10^{-6}
Thermal Conductivity	Cal/sec/cm ² /°C/cm	4.6.8	ASTM C-177	
Type I	Minimum			6×10^{-4}
Type II	Minimum			15×10^{-4}
Thermal Weight Loss	Percent	4.6.9	7041	
Type I	Maximum			3.70
Type II	Maximum			0.42
Thermal Shock Resistance	Cycles (Min)	4.6.10		5
Flammability		4.6.11	2021	
Thermal Vacuum Weight Loss	Percent	4.6.12	ASTM E-595	
Type I	Maximum			1.0
Type II	Maximum			1.0
Condensables	Percent	4.6.12	ASTM E-595	
Type I	Maximum			0.25
Type II	Maximum			0.1
Water Absorption	Percent	4.6.13	7031	
Type I	Maximum			0.05%
Type II	Maximum			0.05%
Viscosity and (Pot Life)	CPS, Maximum	4.6.14	ASTM D-2393	
Type I	(Hrs., Minimum)			20,000 (2)
Type II				4,000 (2)

G. Supplier's Philosophy of Repairability

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Furane Products Div.
M&T Chemical
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REPAIRABILITY:

A MATERIALS SUPPLIER'S VIEWPOINT

Mac Larsen

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When considering the idea of repairability, several contradictions come to mind.

- 1) Many electrical applications require plastics that must withstand service temperatures in excess of 200°C. and potentials of over 50,000 volts. When one has a need to repair a malfunctioning device encapsulated with such a material, he soon finds out just how tough this kind of plastic can be.
- 2) The ever increasing delicacy of electronic devices such as glass diodes, semi-conductors with bonded gold wires, or stress sensitive coils, require tough, highly filled plastics to protect them and attempts to cut into such an encapsulated circuit may cause more damage and take longer than the repair is worth.
- 3) When plastic is designed to be humidity resistant, ozone resistant, and insoluble in organic solvents, it also is going to be very impervious to most chemicals used as strippers.

So what is the plastics engineer supposed to tell a distraught electronics engineer when he finds that 400 circuitboards were assembled with the wrong parts and that the new tough heat and chemical resistant plastic everyone was so proud of has just hardened to a 95 Durometer D? The answer can be very involved. This may be an exaggeration, but it does illustrate the point that repair cannot be an afterthought of design. As the prices and availability of specialized parts become more and more of a concern, or the importance of failure analysis to trouble shoot becomes evident, the engineer must begin to consider how the protective embedment material can be removed upon demand. One can search for a specialized

process to remove the plastic. He can also design the final part with an easily removable material with the possibility of sacrificing some quality or reliability. Understanding techniques, plastics and design for repairable items is becoming an important facet of the electronics industry. The plastics engineer has much to offer this field because he understands the chemical's impact on ultimate performance. This paper is intended to help the electronics design engineer understand the reasons for material removal, describe some established techniques, and offer some new techniques to ease the task of plastic removal.

Some of the more prevalent reasons for justifying removal or repair of electrical/electronic devices are:

- Replacement of defective part
- Molding flaws
- Failure Analysis
- Calibration/Recalibration
- Recovery

1) Replacement (or repair)

This type of repair requires a fairly accurate diagnosis of where the malfunctioning portion is located. In most cases, it is not feasible or desirable to remove all of the coating or encapsulant in order to remove and replace only one part. One would like to go directly to the part, replace it, and refill the void with the same material or possibly a specially designed repair material. This process may be a field repair where time and equipment are at a minimum, and certainly the environmental problems can pose a particular problem such as in the repair of underground telephone cables. In this case, original materials

must be easily removed and a field pack of the repair material, such as a soft urethane, must be insensitive enough to cold and moisture so it will transform from the liquid state into a soft rubber, once mixed and poured onto the cable repair area.

2) Process Flaws

Whether or not there is a significant production volume, there will always be a statistical relationship of good parts to rejected parts. The ability to correct flaws occurring in molding or coating processes, for instance, may be the area that makes or breaks a profitable item. In the case of flexible cable molding, the mold is treated with a release agent which allows the final cured part to be easily removed from the cavity. It is possible to incompletely cover the cavity with the release agent, causing the cable to adhere and rip as it is pulled away. Since much time has already been spent in the setup of the wires, etc., it becomes economically feasible to repair this portion. The most practical repair technique is to use the same material in a fresh mix, put the cable back into the mold, and pour the material in. In some cases it is necessary to clean the surface of the cable with a solvent and/or abrade the surrounding surfaces with fine emery cloth before filling with fresh material, so the freshly hardened material will adhere to the previously molded area.

3) Failure Analysis

An important facet of any R&D program is to determine why a failure occurred. And just as important is the technique used to dissect the faulty device for inspection. For instance, semi-conductor devices are put through tremendous stresses during molding processes, and if they malfunction there is reason to believe that inspection could shed some light on how to better design the part or process.

To analyze such a device, it is important that a delicate technique must be used so as not to incur additional damage. A widely used technique used here is to drop red fuming Nitric Acid onto the plastic and allow to soften or degrade the surface which can then be rinsed with acetone. Several cycles of this process will expose the chip without harming the lead frame or chip. The Nitric Acid must be very low in moisture in order to prevent it from reacting with and destroying the metallic components within the molded package.

4) Calibration

A little forethought here always helps. A device such as a trim pot, used in many circuits, must be exposed in order to be adjusted. Naturally, the easiest technique is to cover it with a soft material then encapsulate the entire circuit. When adjustment becomes necessary, one needs only to drill through the encapsulating plastic, then remove the soft covering and calibrate. Some suggestions for removable materials are: a high temperature wax, soft staking compound such as silicone or urethane, or possibly a small piece of zinc chromate tape. These are either soft or thermal plastic materials which, depending on the electrical requirements, can remain with the device or be removed. The wax can be melted out, while the soft polymers or tapes can be cut and removed.

5) Recovery

This reason for embedment removal justifies the most destructive type of process. Although recovery of precious metals or parts is strictly speaking, not a repair item, it is valuable when parts are needed immediately but have an intolerable delivery time. Any type of removal technique can be used, providing that the sought after item can withstand it.

All of the examples given above can be catagorized into one of three techniques of plastic removal.

Thermal

Mechanical

Chemical

Just about any way one can think of to remove plastic will fall into one of these three classifications. Indeed, some techniques involve two or even all three of these groups. What is important to remember, however, is that the more stringent the requirements of the plastic, the more difficult the task is to remove or repair it.

As repair becomes more important, there are certain sacrifices that must be made in performance and reliability and/or cost of production in order to satisfy the repairability parameters. Some property considerations that should be thought of in the design of either a repairable or non-repairable device are listed below.

(Materials are listed in increasing difficulty to repair).

<u>Material</u>	<u>Advantages</u>	<u>Disadvantages</u>
Thermoset Gel (Silicone Gel)	Re-enterable Extreme ease of removal	No support - Environmental Resistance low; high cost
Soft Thermoplastic (Urethane, Polyethylene)	Easily melted or cut with hot knife	Low solvent resistance Low service temperatures
Soft Thermoset (Silicone, Urethane)	Moderate ease in cutting Good electricals possible	High cost - Silicones
Hard Thermoplastic (Polyimides, PPS)	Can be dissolved at high temp; good electricals	Processing scale up; expensive Temp required to melt too high for practicality
Hard Thermoset (Epoxyes, Phenolics)	Excellent electricals High temp service Good environmental resistance	Very difficult to dissolve, break, or melt

A technique that was investigated for the purpose of this paper involves Binary system encapsulation. What this process tries to do, is obtain the best of two worlds. That is mold a soft, repairable material directly around the repairable device then over encapsulate with a hard thermoset material, thus protecting the more vulnerable inner material against the effects of humidity, abrasion and shock. Upon the event of a repair, the hard outer casting can be opened up by mechanical means such as sawing to expose the easily cut soft polyurethane. Figure 1 shows a cast part and a cross sectioned piece to illustrate the construction. A total of four types of castings were made:

<u>Inner Casting</u>		<u>Outer Casting</u>	
A) Unfilled polyurethane (Durometer 60A)		Unfilled epoxy (Durometer 85D)	
B) Filled polyurethane	"	" "	"
C) Unfilled polyurethane	"	Filled epoxy	"
D) Filled polyurethane	"	" "	"

The reason for filling is to adjust the thermal expansion rates to minimize internal stresses that may produce cracks. This concept is already used widely in potting processes, whereby a fluid potting material is poured into a thermoplastic case. In this example, unless the filling port is hermetically sealed, the soft repairable inner material would be subjected to possible harsh environments such as humidity, ozone, acids, or nitrous oxides. By overcasting with a thermoset as described above, a hermetically sealed package is automatic with the only openings or areas of possible contamination being wires or connectors. With proper planning regarding mechanical design, a hermetically sealed re-enterable system is possible. Figure 2 shows the effect of thermal cycling. After 3 cycles of -55 to 100°C., cracks appear in the unfilled epoxy but none in the filled version.

Finally, to demonstrate the actual repairability of the system, Figure 3 shows a cut casting which exposes the urethane inner material. A razor blade, or perhaps a soldering iron with a knife edge, can be utilized to slice the polyurethane away. Figure 4 shows another clear soft durometer polyurethane that a hot instrument can readily penetrate thus enabling the technician to remove large chunks to expose faulty devices. Certainly this concept can be investigated to a much greater degree; however, internal design of electrical/electronic parts is such an important consideration of the package in its entirety, that one would have to design an epoxy/urethane system to match the requirements.

There has been much research into chemical means of removing plastics. Much has been written on the subject with entire product lines being built on a variety of strippers. As mentioned before, many electrical/electronic applications require thermally stable solvent resistant thermosets to adequately protect sensitive circuits. In most cases, a non-repairable material is one with these properties, and although it provides the best reliability it seldom affords itself to repair.

The concept most widely used to remove plastics, particularly thermosets, is to break apart or digest the polymer so it becomes more soluble. These chemicals can become very specific to generic types of polymers such as anhydride cured epoxies, silicones, etc. Once the chemistry is known, the selection of proper strippers is somewhat edisonian in practice. Generally, the thicker the cross sectional area, the harder it is to remove. Mechanical means of burning, sawing, or cutting off heavy layers can be used in conjunction with chemical methods. This is all labor intensive and so the reasons for repair become more and more critical to cost.

In deciding what kind of chemicals and methods to use to remove plastics there are several considerations to be taken.

- 1) Will the chemical be selective enough to stop dissolving when critical parts are uncovered?
- 2) Will any residual contaminants, such as acids, harm metal contacts or wiring even after the repair job is finished?
- 3) Are the chemicals toxic? Can they be readily disposed?
- 4) Will refluxing or other potentially expensive equipment be required?

Table I gives some idea of the variety of chemicals that are used to remove plastics. Unfortunately, in most cases, their performance does not outweigh their toxicity. There are combinations that have proven to be useful such as the following formula developed by G. R. Sprengling, Westinghouse R & D, and published in February, 1980 issue of Insulation Circuits.

50% Tall Pitch

25% b Naphthol

25% Triethene Glycol

According to Sprengling, this "standard stripper" was found effective in dissolving all common insulating thermosets in a time of 1-6 hours @ 250°C. This exemplifies the supposition that there does exist combinations of chemicals that when mixed together will reverse the polymerization process resulting in the removal of plastics.

A proprietary mixture of non-corrosive chemicals was made for this paper to illustrate the reverse polymerization process and demonstrate selectivity of a stripper for various plastics. The items chosen for illustration were epoxy dip-coated hybrid circuits and polyurethane encapsulated cable connectors.

The setup was oversimplified for purpose of illustration. A 500 ml Beaker was placed on a hot plate, filled 1/2 full with the stripping solution, heated to 70°C and was kept agitated by a Teflon coated magnetic stirrer which, by the way, was unharmed after hours of stirring. A round bottom distilling flask was filled with ice water to act as a refluxer. When fumes contact the cold flask, they condense and drip back into the beaker. A refluxing column could have been used; however, it would have made removal of parts more difficult for picture sequencing. Figure 5 shows before and after circuits with the small piles of undissolved resin above each board. Notice that some of the components on the right board are damaged from the solvent. The coatings used on these particular devices are similar to the circuit coating so the solvent could not be selective. Everything else on both boards, however, remain untouched, including the metal leads and copper cladding. An interesting observation here was that epoxy molded devices are virtually untouched by this stripper as well as epoxy/glass printed circuit boards.

The second set of figures show the removal of a polyurethane encapsulant from around a molded cable. Again, notice the before and after devices (Figure 6) and how the metal is still shiney, the wire insulation is intact and the termination (Diallyl Phthalate) piece is untouched. An important point to make is that the cable can now be repaired (re: soldering, adjusting of possible shorts, etc.) and that no additional damage was done to the actual electrical connections.

Many other repair techniques are used in the electrical/electronics industry and they are becoming more and more commonplace. Certainly the fact that it is possible to design a device with a removable embedment material just supports the expectations that plastics will continue to enjoy the paralleling high rate of growth with electronics. And it is becoming more and more evident that a close relationship must continue between electrical and plastics engineers in order to meet the ever increasing demands.

TABLE I
EXAMPLES OF STRIPPERS

Acetic Acid
Formic Acid
Nitric Acid
Sulfuric Acid
Phenol
Sodium Hydroxide
Ammonium Hydroxide
Di Butyl Amine
MDA
Tall Pitch
Naphthol
1, 4 Butane Diol
Tri Ethylene Glycol
Methylene Chloride
Perchloroethylene
Methyl Ethyl Ketone
M-Pyrol
Dimethyl Formamide
Phthalic Anhydride

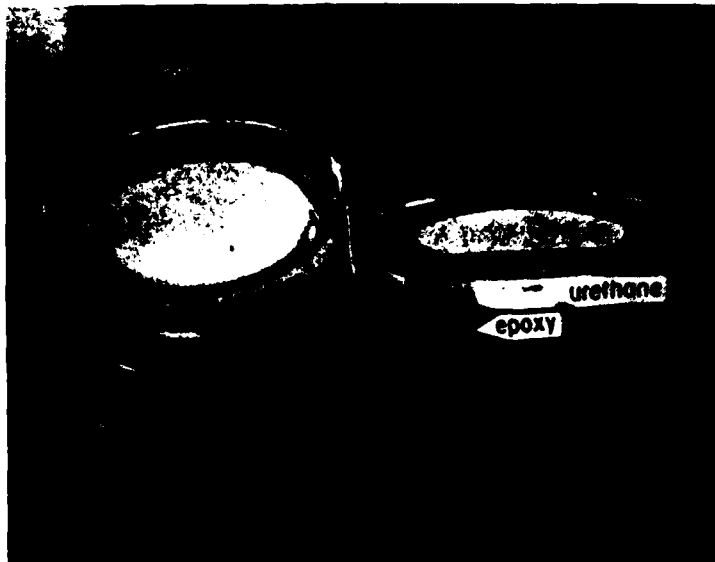


FIG 1



FIG 2



FIG 3



FIG 4



BEFORE



AFTER

FIG 5

**URETHANE MOLDED
CABLE**



**CHEMICALLY
STRIPPED
URETHANE MOLDED
CABLE**

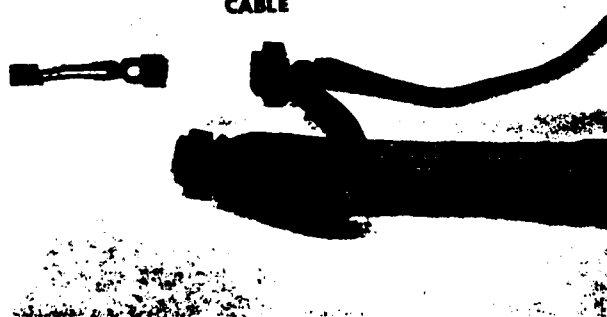


FIG 6

**URETHANE MOLDED
CABLE**



**CHEMICALLY
STRIPPED
URETHANE MOLDED
CABLE**



FIG 6

H. Embedment Material Selection Considerations
 for Repairability

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HUGHES

SELECTION OF EMBEDMENT MATERIALS AND DESIGN FACTORS

FOR THE REPAIRABILITY/REWORKABILITY OF ELECTRONIC MODULES

O. DALE SMITH

JUNE 15, 1981

HUGHES

INTRODUCTION

- HISTORICAL BACKGROUND
- WHERE WE ARE TODAY

HUGHES

EMBEDMENT MATERIAL

A POLYMERIC PACKAGE THAT ENCLOSES ELECTRICAL OR ELECTRONIC
HARDWARE THEREBY PROVIDING PHYSICAL AND ENVIRONMENTAL
PROTECTION

HUGHES

EMBEDMENT MATERIAL

BOTH REPAIR AND REWORK OPERATIONS REQUIRE THE REMOVAL OF AN EMBEDMENT MATERIAL. THIS EMBEDMENT MATERIAL MAY BE EITHER A COATING, POTTING OR ENCAPSULATING COMPOUND WHICH IS POLYMERIC IN NATURE.

HUGHES

REPAIR

THE ACT OF RESTORING DAMAGED ELECTRICAL OR ELECTRONIC
HARDWARE TO A NORMAL OPERATING CONDITION WITHOUT
SACKIFICING ITS INTENDED PERFORMANCE CHARACTERISTICS.

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REWORK

THE ACT OF REVISING ELECTRICAL OR ELECTRONIC HARDWARE TO
NEWER DESIGN CRITERIA OF PERFORMANCE CHARACTERISTIC
WHICH IS GENERALLY MINOR IN NATURE.

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NEED FOR REPAIR

REFURBISHMENT

- COMPONENT FAILURE

STATIC DISCHARGE DAMAGE

IN-PROCESS SOLVENT DAMAGE

TEMPERATURE SENSITIVITY

- CIRCUITRY FAILURE

WORKMANSHIP DEFECTS

LATENT DEFECTS

NEED FOR REWORK

MODIFICATION

- PART SUBSTITUTION

- UPGRADE FOR NEWER CAPABILITIES

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REPAIR AND REWORK BENEFITS

- SUBSTANTIAL COST SAVINGS
- SALVAGE OF IRREPLACABLE PARTS/HARDWARE
- PRECIOUS METAL RECLAMATION

HUGHES

NEED FOR REPAIR

REFURBISHMENT

- COMPONENT FAILURE

STATIC DISCHARGE DAMAGE

IN-PROCESS SOLVENT DAMAGE

TEMPERATURE SENSITIVITY

- CIRCUITRY FAILURE

WORKMANSHIP DEFECTS

LATENT DEFECTS

NEED FOR REWORK

MODIFICATION

- PART SUBSTITUTION

- UPGRADE FOR NEWER CAPABILITIES

HUGHES

WHY NOT TOTAL PART REPLACEMENT?

- UNAVAILABILITY OF DISCONTINUED PARTS
- LONG LEAD TIME FOR SYSTEM READINESS
- EASE OF REPAIRABILITY
- LOWER COST

HUGHES

TRADITIONAL TYPES OF REMOVAL

- CHEMICAL
- MECHANICAL
- OTHER

HUGHES

SELECTION OF EMBEDMENT MATERIALS BASED ON:

- PHYSICAL PROPERTIES
- ELECTRICAL CHARACTERISTICS
- CHEMICAL RESISTANCE

HUGHES

TYPES OF EMBEDMENT MATERIALS

ACRYLIC

POLYURETHANE

SILICONE

EPOXY

POLYSULFIDE

FLUOROSILICONE

POLYIMIDE

PARYLENE

FACTORS TO CONSIDER FOR ELECTRONIC MODULE EMBEDMENT REPAIRABILITY

PROPER MATERIAL SELECTION

- USE OF GENERICALLY DIFFERENT MATERIALS
- USE OF HEAT CURE MATERIALS ADJACENT TO ROOM CURE MATERIALS
- USE OF BARRIER COATINGS

PROPER DESIGN

- ACCESSIBILITY OF TROUBLESOME HARDWARE
- CHOICE OF COMPONENTS COMPATIBLE WITH THE FIELD ENVIRONMENT
- AVOIDANCE OF HIGHLY DENSE CIRCUITRY DESIGNS
- USE OF STANDARDIZED COMPONENT/HARDWARE

I. Repairable Potted High Voltage Assemblies

Bob Swendsen
Northrop Corp.
Rolling Measows, IL 60008

REPAIRABILITY OF POTTED HIGH VOLTAGE ASSEMBLIES

R. SWENDSEN

NORTHROP
Northrop Corporation
Defense Systems Division
156-027942-003

● GENERAL DESIGN CONSIDERATIONS

● MATERIAL SELECTION

● REPAIR TECHNIQUES

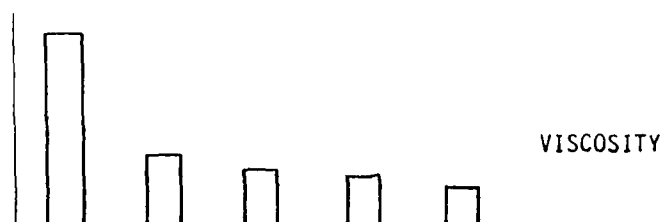
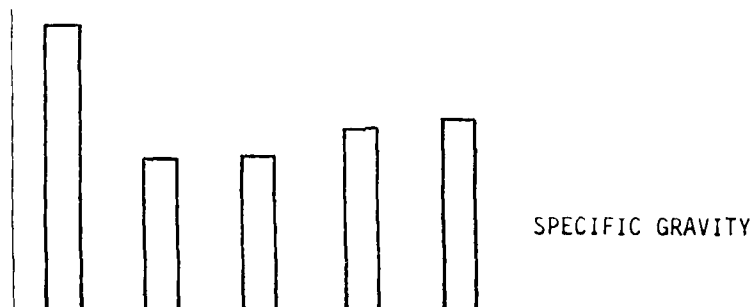
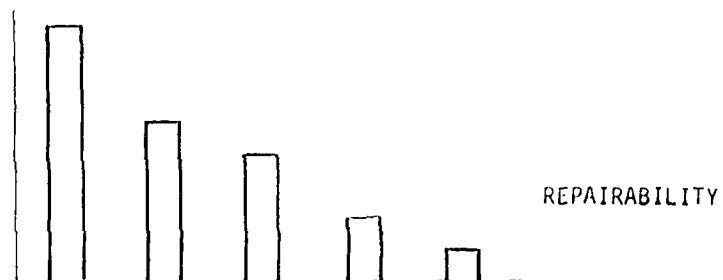
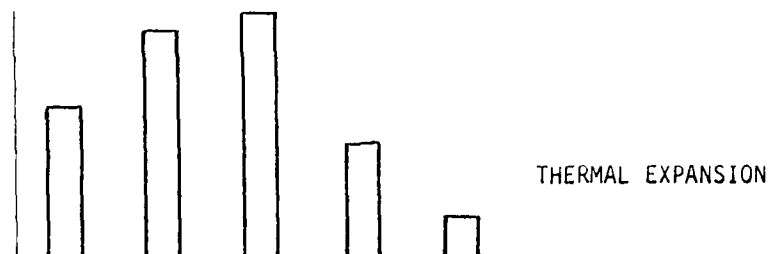
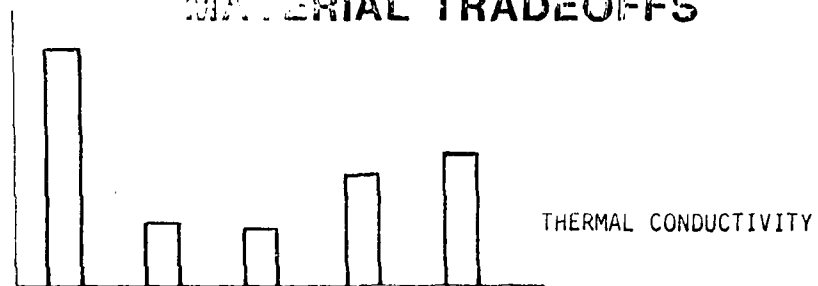
● PLUG-IN HIGH VOLTAGE MODULES

GENERAL DESIGN CONSIDERATIONS

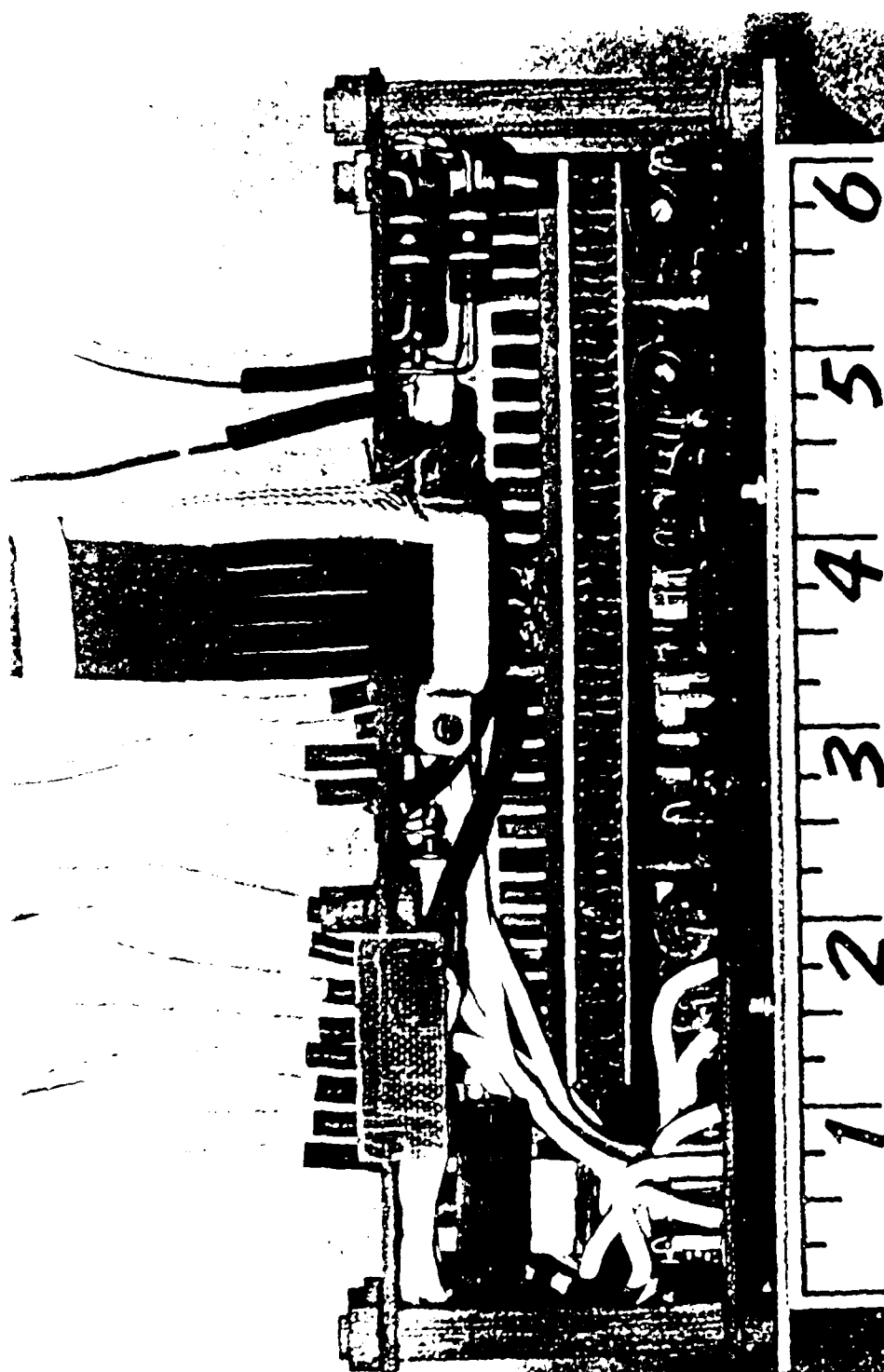
- REPAIRABILITY
- MAINTAINABILITY
- MANUFACTURABILITY
- RELIABILITY/LIFE
- HEAT TRANSFER
- SIZE AND WEIGHT
- LIFE CYCLE COST

155-027942-001

MATERIAL TRADEOFFS

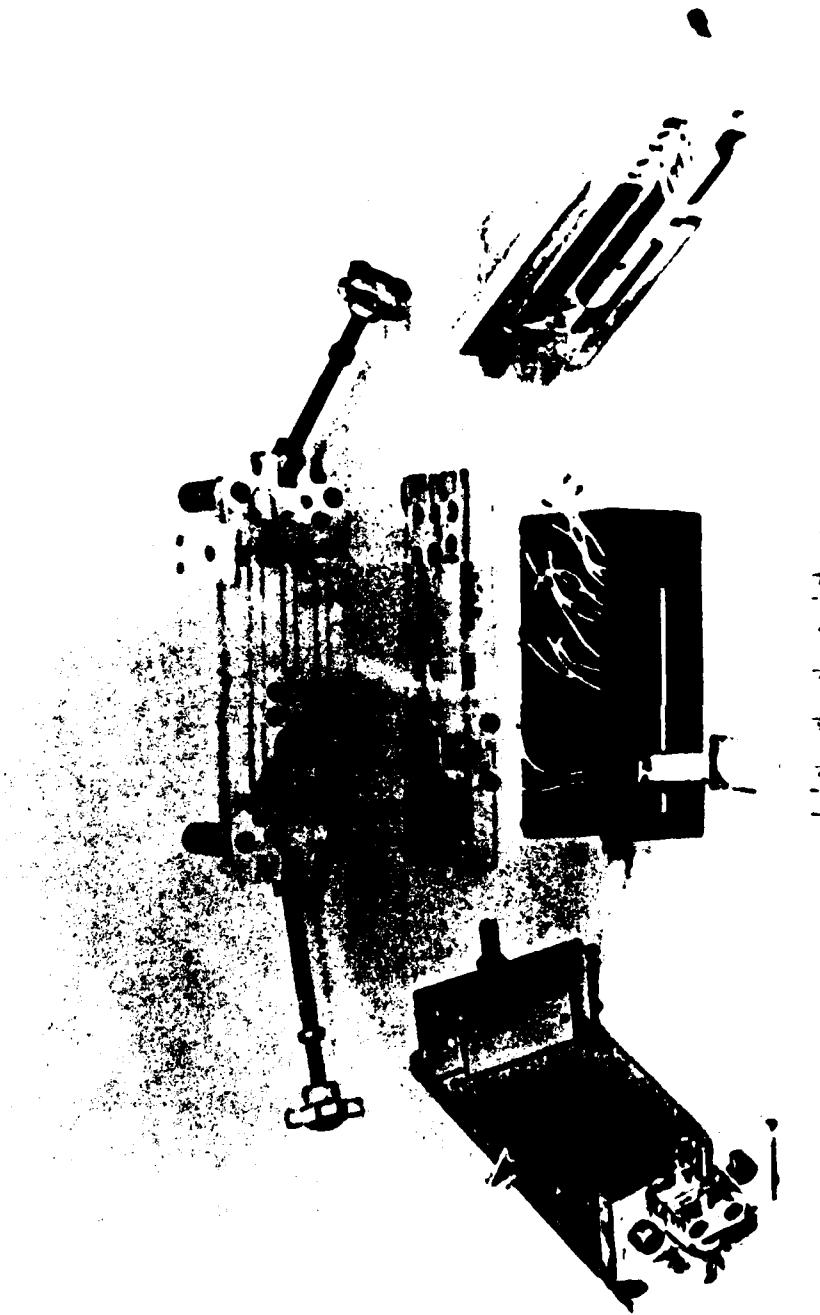


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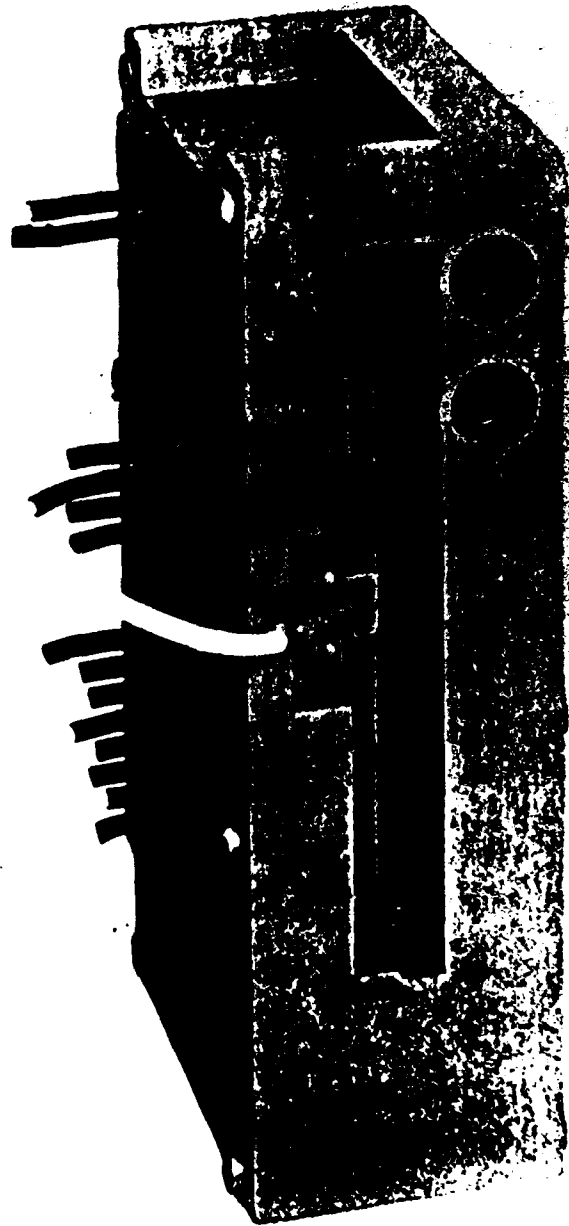


HIGH VOLTAGE MODULATOR

MODULATOR MOLD



POTTED H.V. MODULATOR



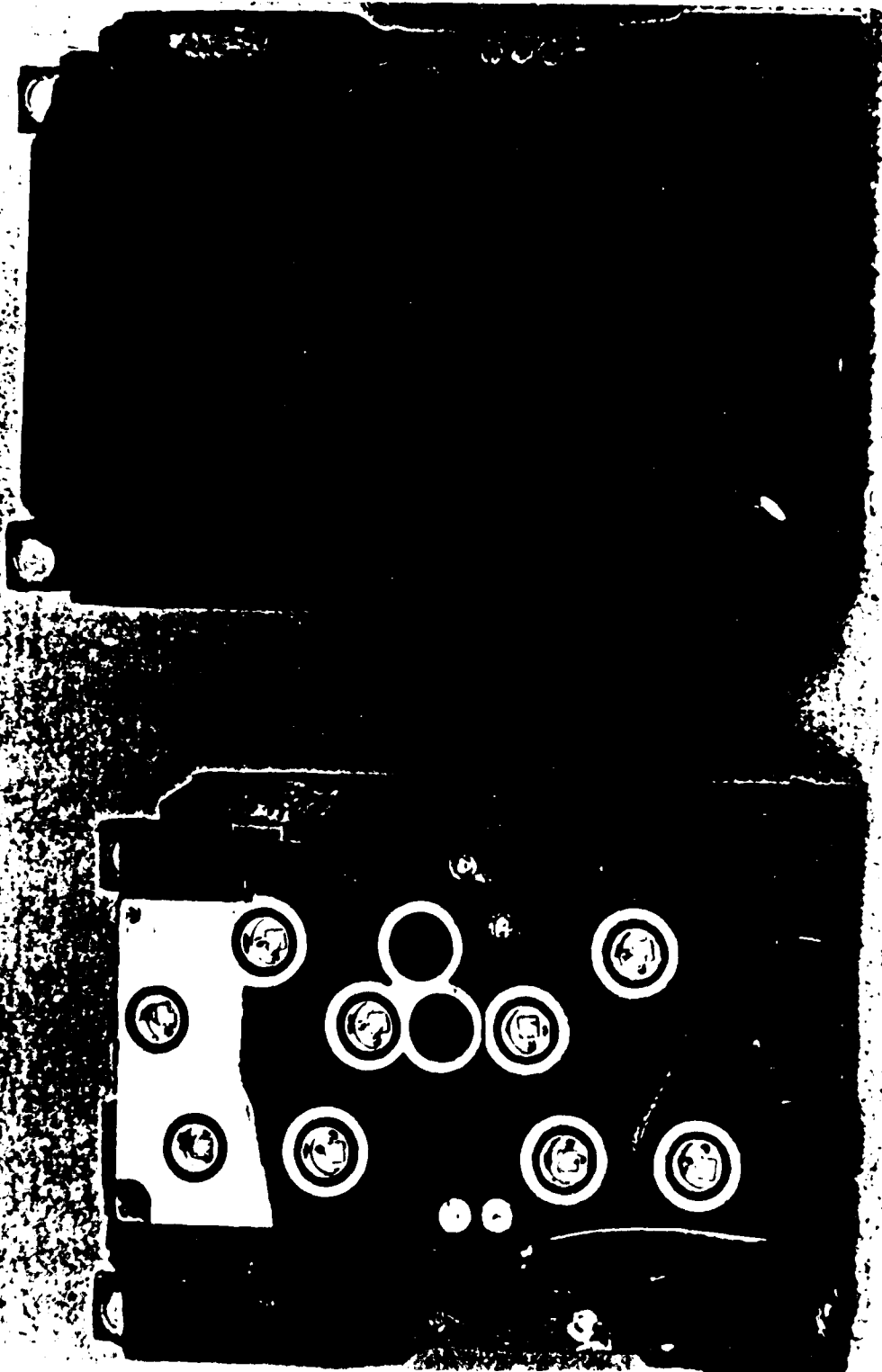


HV MODULATOR UNDER REPAIR



HV MCEB... REPAIR

H.V. MODULATOR UNDER REPAIR



NORTHROP
1 1 2 3

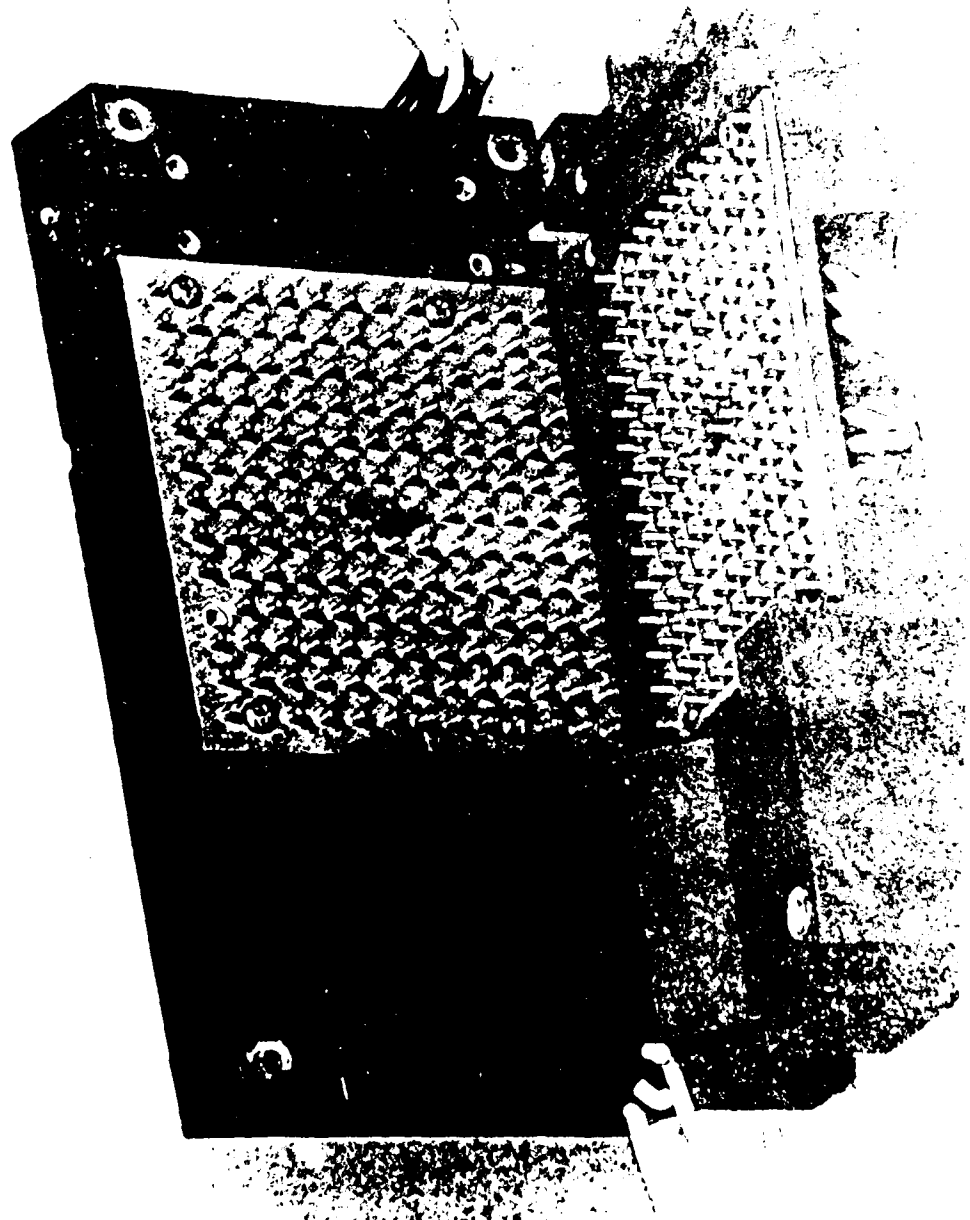


HV MODULATOR UNDER REPAIR

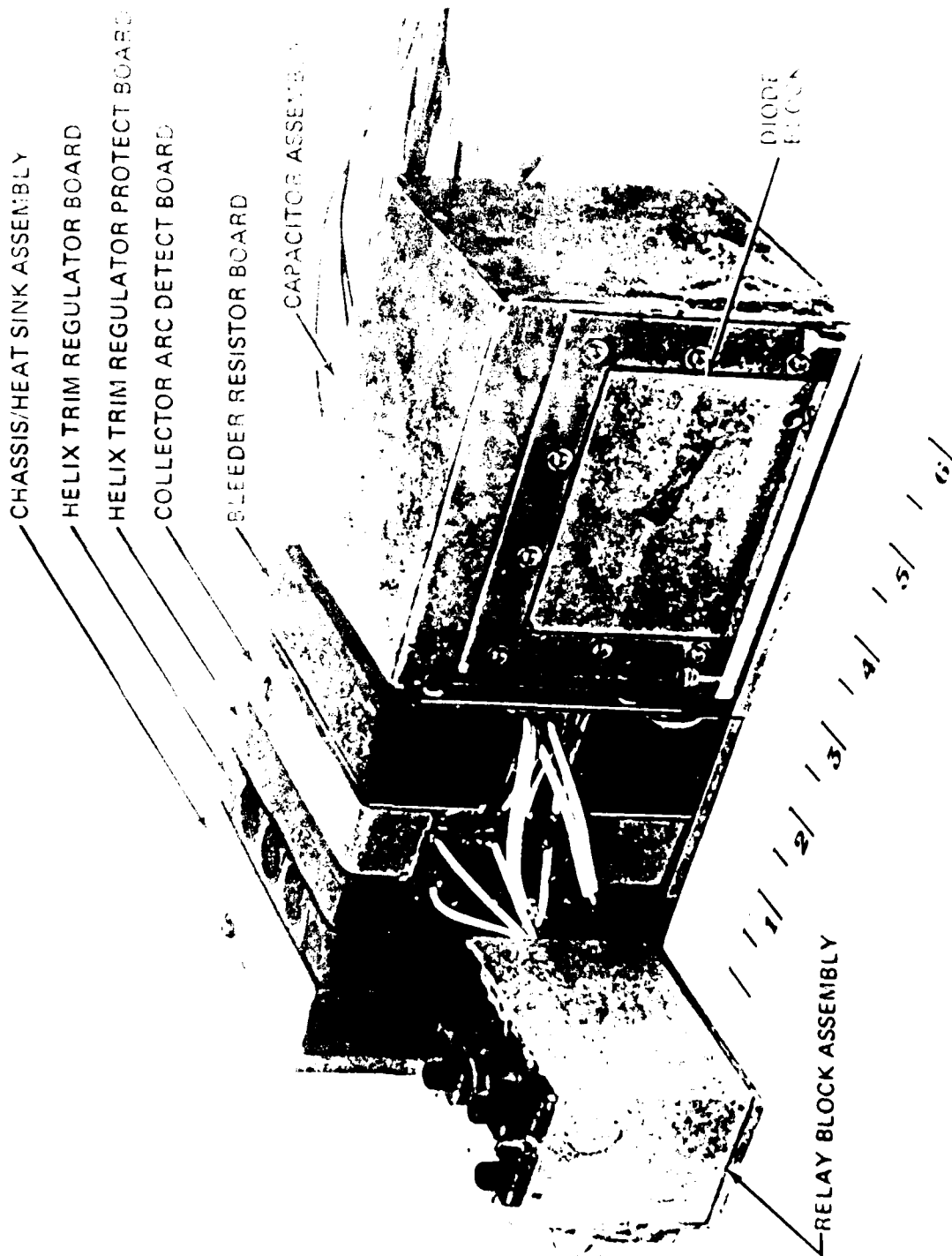
TWO PIECE H.V. MODULATOR



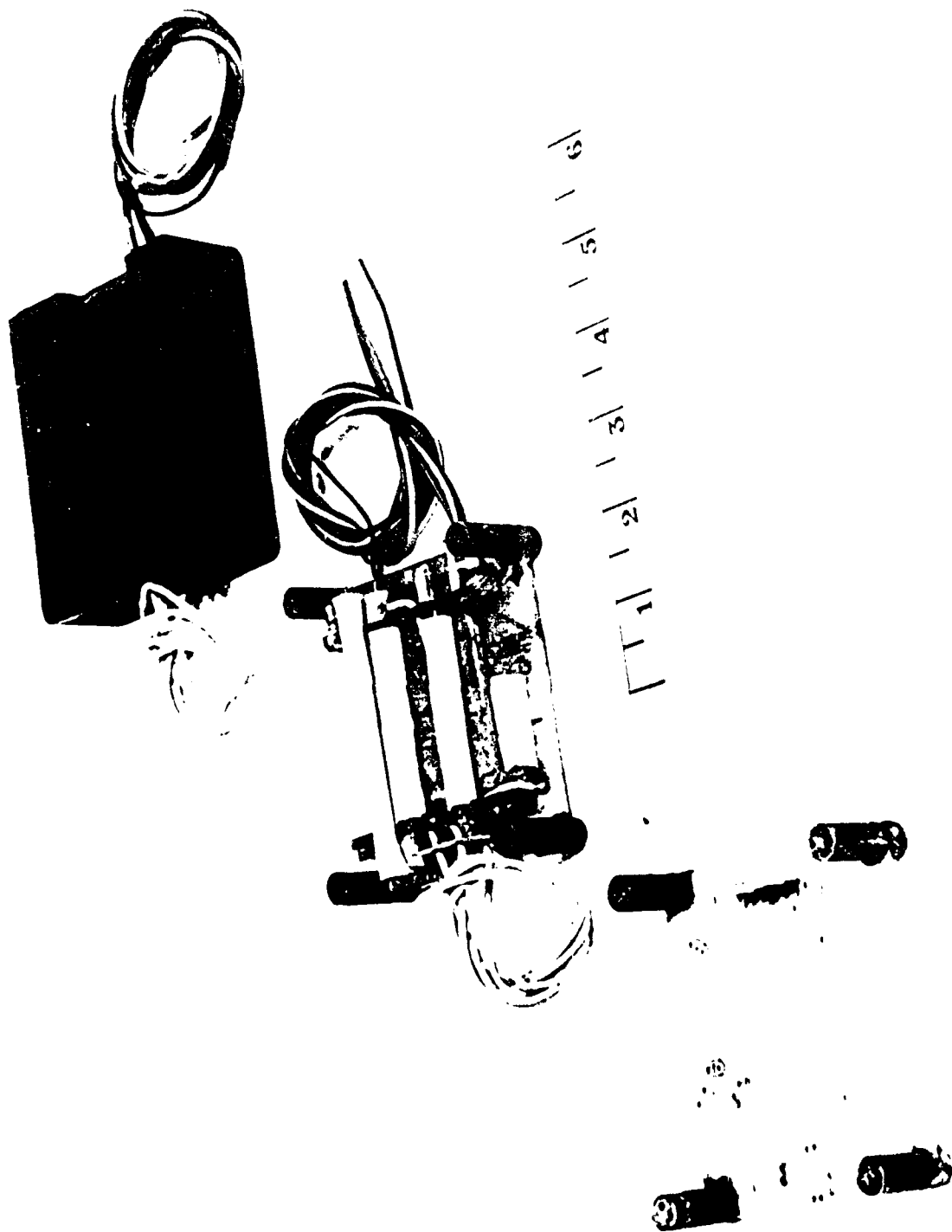
TWO PIECE H.V. MODULATOR



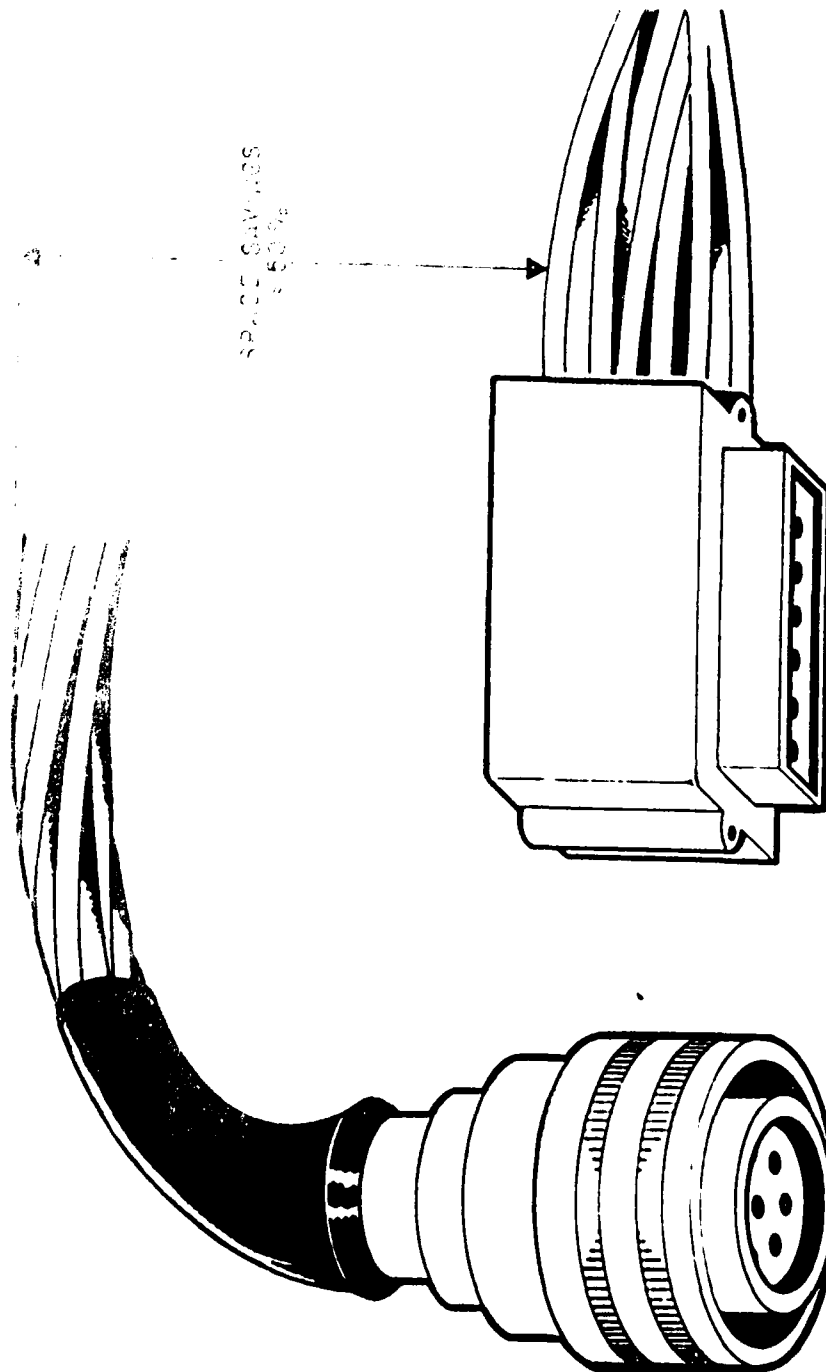
MODULAR H.V. ASSEMBLY



H.V. MODULE-ASSEMBLY STAGES



CONNECTOR CONFIGURATIONS



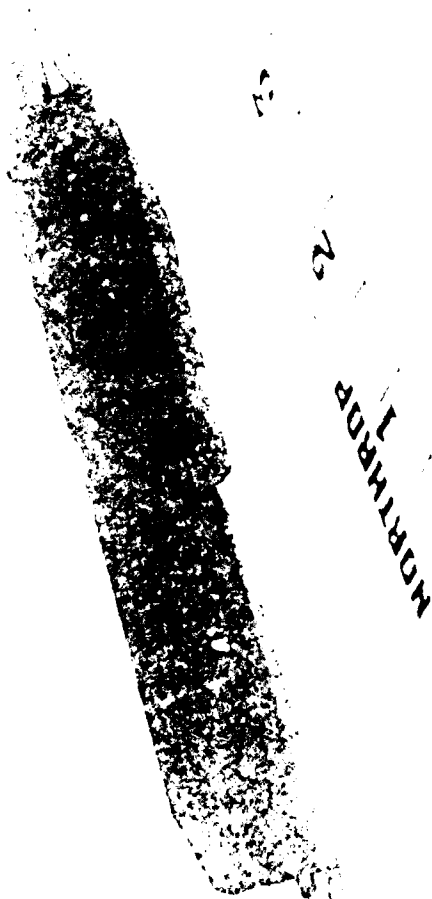
a. TYPICAL CYLINDRICAL
CONNECTOR NOW USED

b. LINEAR CONNECTOR
BEING STUDIED

100-125-100



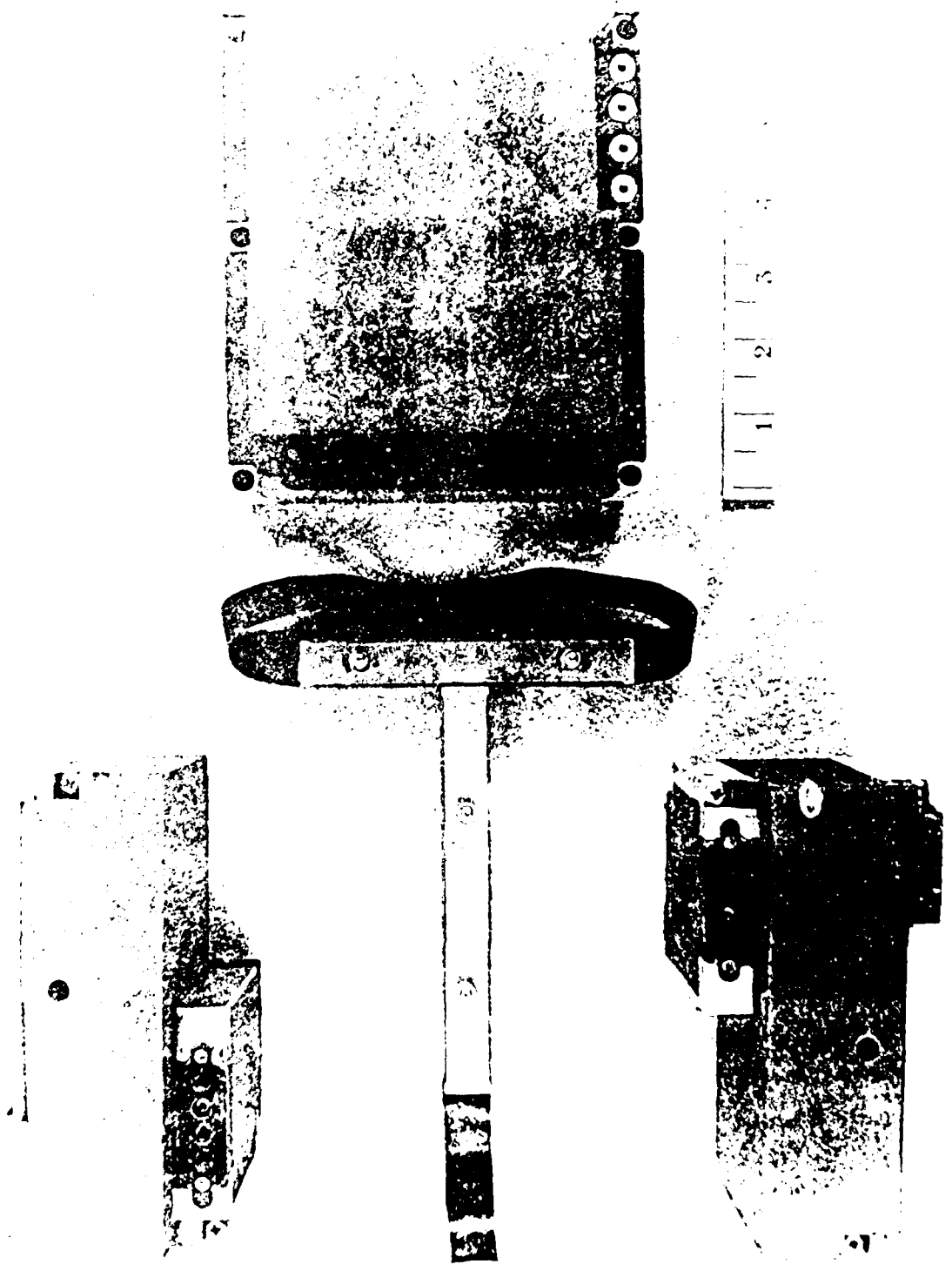
NORTHROP 1, 2, 3,

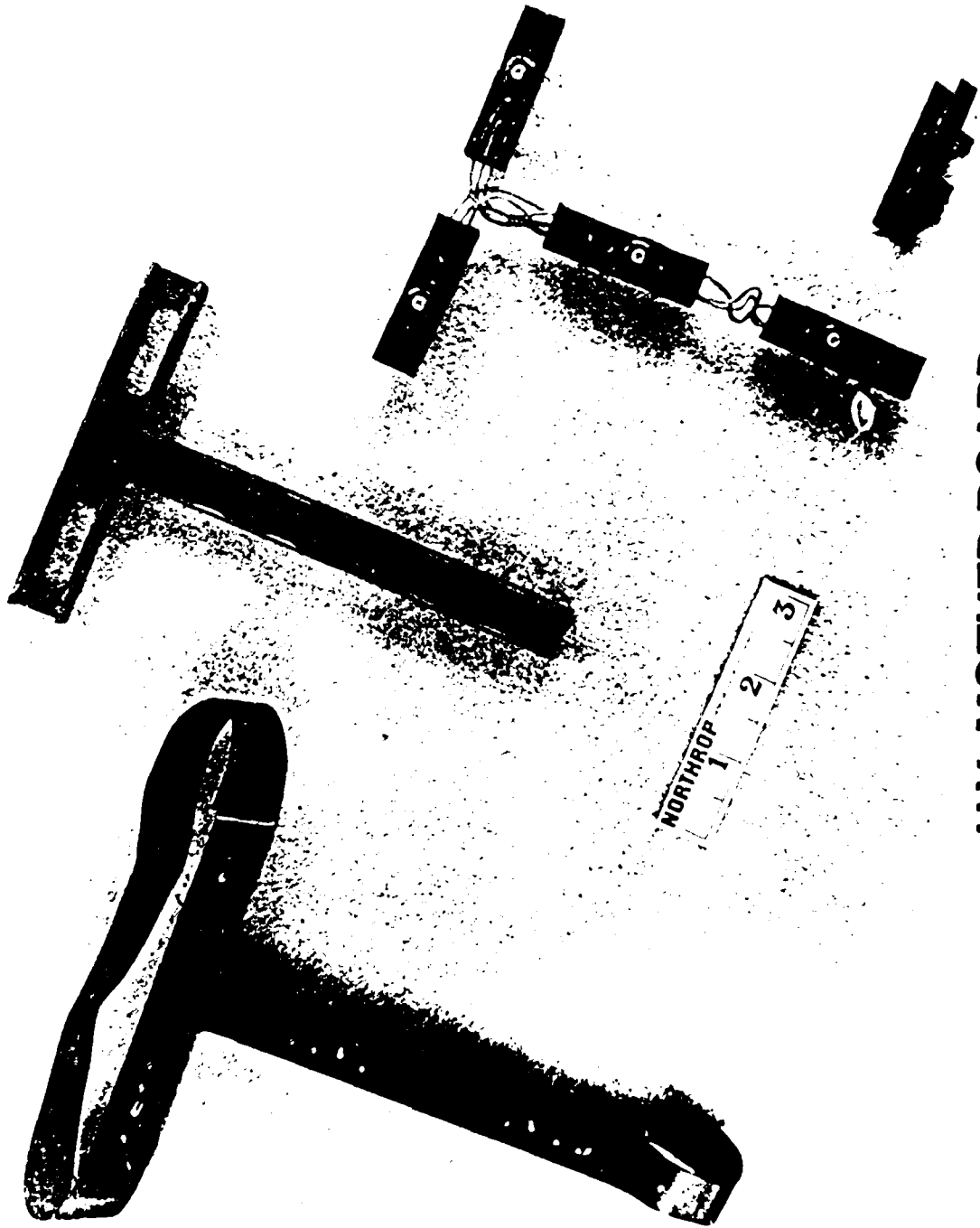


PLUG IN MODULE CONNECTOR



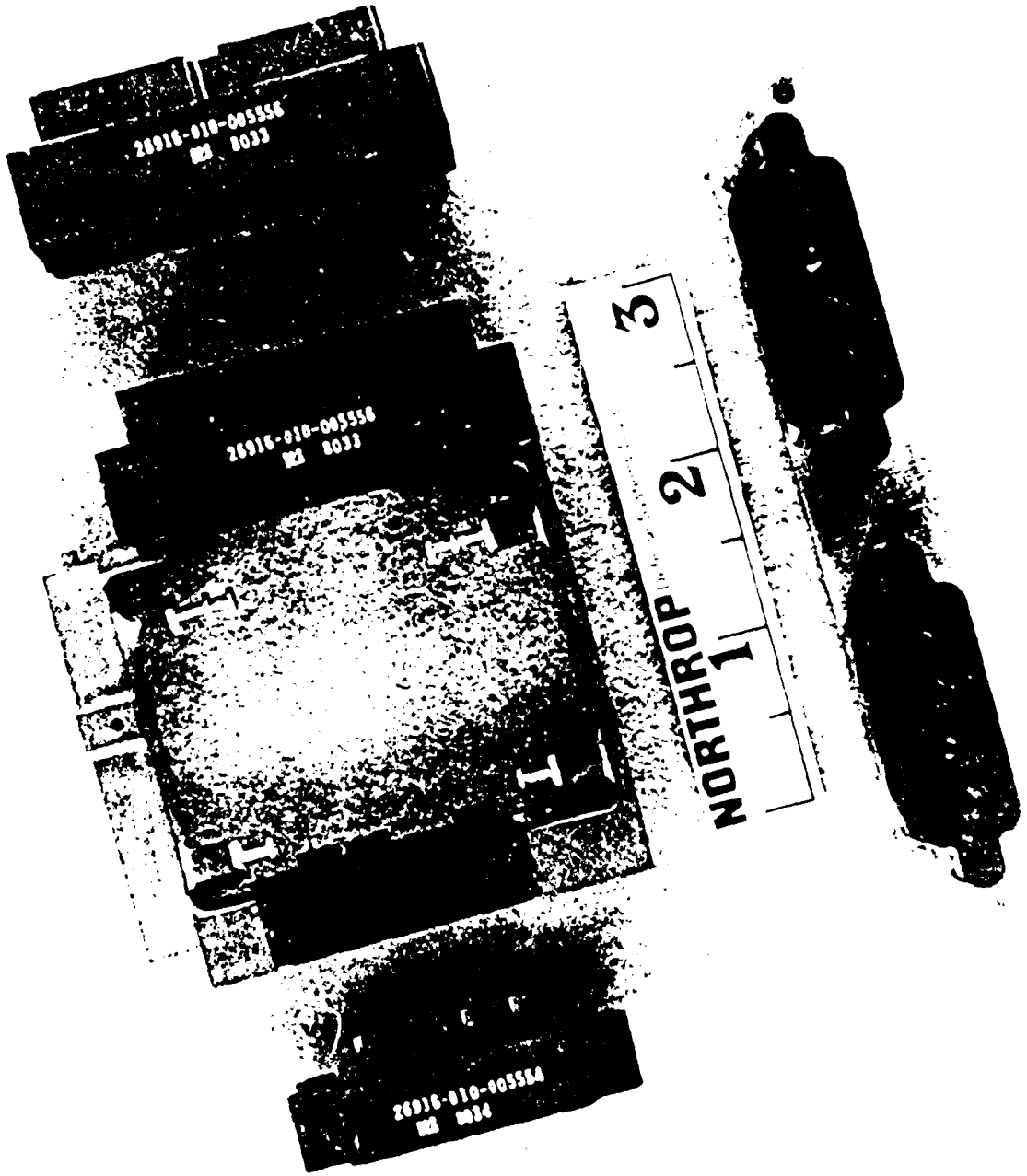
PLUG IN H.V. MODULES



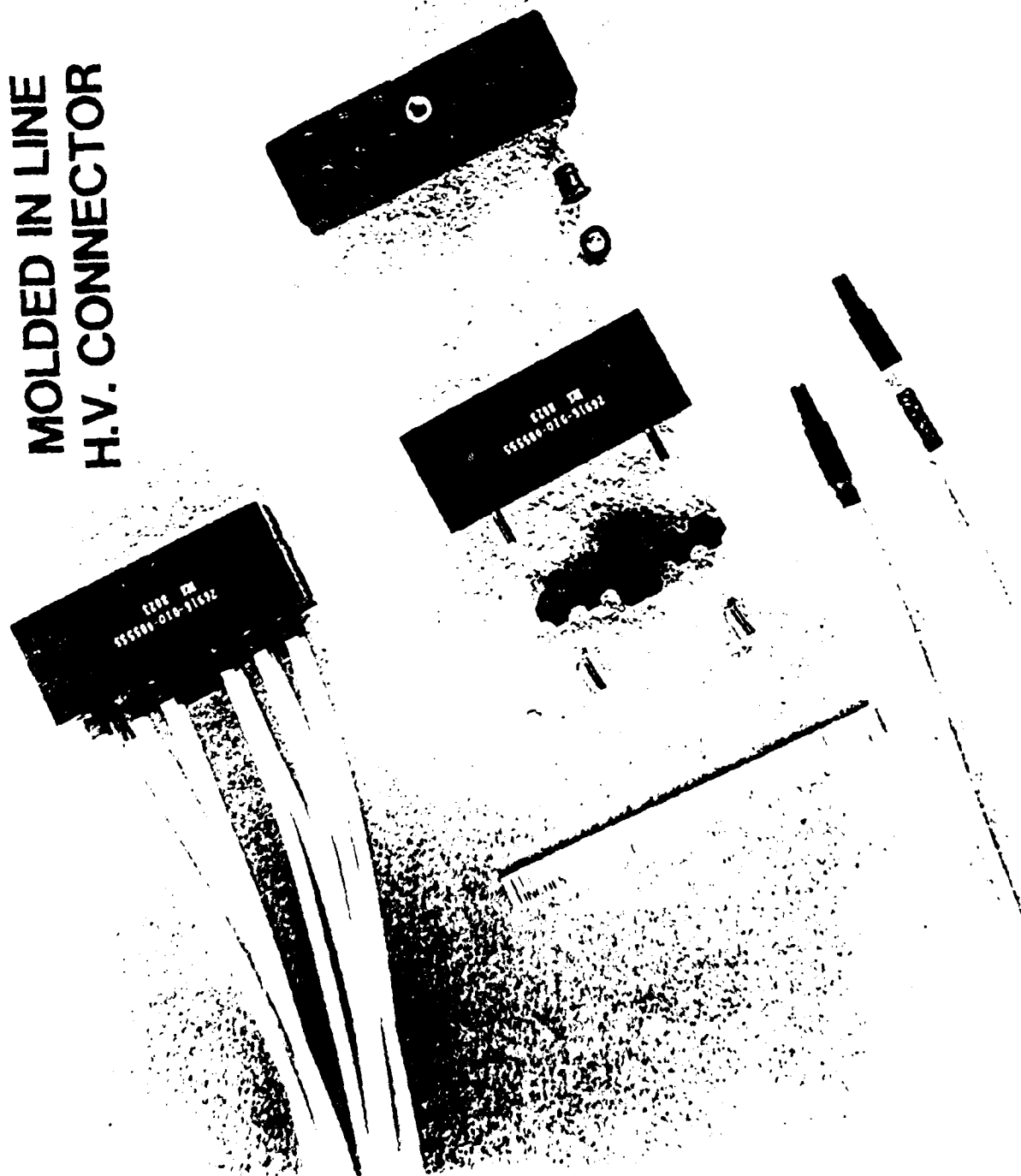


H.V. MOTHER BOARD

MOLDED H.V. CONNECTOR ASSEMBLIES

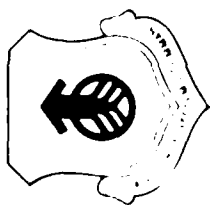


MOLDED IN LINE H.V. CONNECTOR

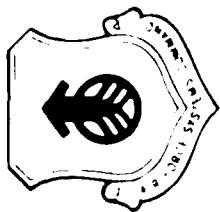


J. Air Force Response to Survey

Lt. Gary Ragsdale
ASD/RAOF
WPAFB, OH 45433

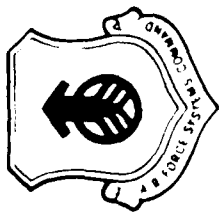


ALC SURVEY ON STANDARDIZATION OF POTTING COMPOUNDS AND SOLVENTS



TOTAL NUMBER OF SURVEY RESPONSES BY ORGANIZATION

AEROSPACE GUIDANCE & METROLOGY CENTER	21
EGLIN AFB	1
OKLAHOMA CITY ALC	6
OGDEN ALC	15
SAN ANTONIO ALC	4
SACRAMENTO ALC	2
WARNER ROBBINS ALC	9
WRIGHT-PATTERSON AFB	3
TOTAL RESPONSES	61



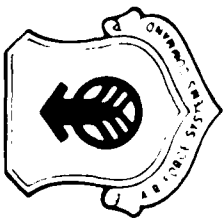
● DO YOU USE POTTING COMPOUNDS ON
YOUR JOB?

YES - 33

52%

NO - 31

48%



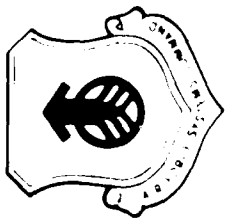
- DO YOU PRESENTLY REPAIR ANY
POTTED ELECTRONIC COMPONENTS?

YES - 21

33%

NO - 43

67%



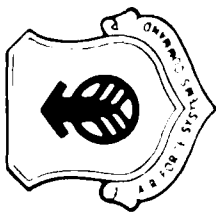
- WHICH TYPE OF RESPONSIBILITY DO YOU HAVE FOR ELECTRONIC COMPONENT USE/OR FOR POTTING COMPOUNDS?

REPAIR - 24 MANAGEMENT - 17 TECHNICAL - 29

34%

24%

42%



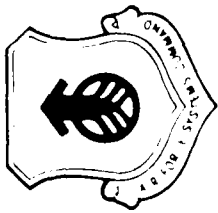
- DO YOU FEEL THAT POTTING COMPOUNDS USED IN ELECTRONIC MAINTENANCE ARE A FACTOR PREVENTING ECONOMICAL REPAIR OF EQUIPMENT PRESENTLY CODED EXPENDABLE AT DEPOT OR FIELD LEVEL?

YES - 48

NO - 10

83%

17%



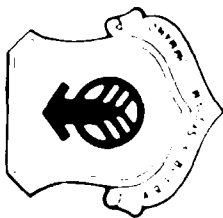
- DO YOU BELIEVE THAT THERE IS A NEED FOR A POTTING COMPOUND FOR ELECTRONIC MODULES THAT WILL PERMIT REPAIR OF THE FAILED ELECTRONICS?

YES - 53

NO - 5

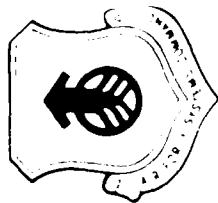
91%

9%

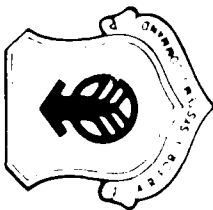


- THESE ARE SOME EXAMPLES OF ELECTRONIC MODULES THAT ARE BEING THROWN AWAY BECAUSE DEPOTTING IS IMPOSSIBLE.

<u>TYPE OF MODULE</u>	<u>#/MONTH</u>	<u>UNIT COST</u>
TITAN MODULES	1-2	\$10K - \$38K
GI-T1-B GYRO	25	\$800.
AF AMPLIFIER	600	\$40. - \$55.
MK-6 CONTROL BOX	8/YEAR	\$25K
		<u>\$100K PER MONTH</u>
		\$1.2M PER YEAR



- THESE ARE SOME OF THE SPECIAL REQUIREMENTS FOR THE ELECTRONIC MODULES THAT ARE BEING DISCARDED BECAUSE THEY CAN'T BE DEPOTTED.
- HIGH VOLTAGE (3000V)
- HIGH SHOCK (100Kg's)
- VIBRATION
- HIGH TEMPERATURE



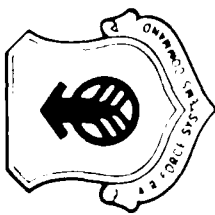
- SHOULD POTTING MATERIALS BE TRANSPARENT?

YES - 47
84%

NO - 9
16%

- REASONS:

- PRO - VISUAL INSPECTION FOR FAULTS
AID IN LOCATING FAILED COMPONENT
MINIMIZE FURTHER DAMAGE WHEN
DEPOTTING
- CON - CONCENTRATED LIGHT MAY AFFECT SOME
MICRO-COMPONENTS
FILLERS ADD DESIRABLE PROPERTIES



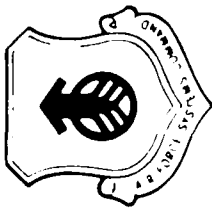
- DO YOU SEE EVIDENCE OF A PROLIFERATION PROBLEM IN THE AIR FORCE WITH POTTING COMPOUNDS USED IN ELECTRONIC REPAIR?

YES - 29

NO - 19

60%

40%



- DO YOU THINK POTTING COMPOUNDS ARE APPLIED IN AREAS WHERE THEY ARE UNNECESSARY?

YES - 15

NO - 35

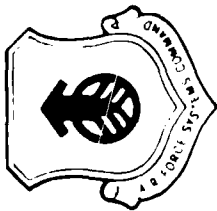
30%

70%

- EXAMPLE: ENCAPSULANTS TO PREVENT COMPONENT VIBRATION ON REPAIRABLE MODULES WHERE HUMIDITY IS NOT A PROBLEM

MASSIVE POTTING WHERE A FILM TYPE WILL DO

ELECTRONIC MODULES HOUSED IN HERMETICALLY SEALED/GAS FILLED CASES



- IS THERE ANY TIME LOST DURING AIRCRAFT/MODULE REPAIR, DUE TO THE MYRIAD OF POTTING COMPOUND FORMULATIONS?

YES - 27

69%

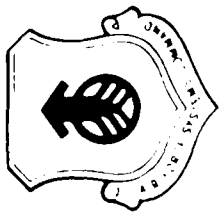
NO - 12

31%

- COMMENTS: PROPORTIONAL TO NUMBER OF COMPOUNDS

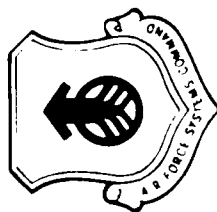
DEPENDS ON SET-UP TIME

DEPENDS ON SUPPLY TIME



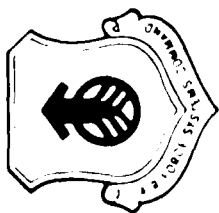
- WOULD YOU PREFER A CHEMICAL OR MECHANICAL MEANS OF POTTING REMOVAL?

CHEMICAL - 42	MECHANICAL - 15	HEAT - 2
71%	25%	4%



● HOW MANY SOLVENTS DO YOU CURRENTLY STOCK TO
DEPOT COMPONENTS FOR REPAIR?

- TOLUENE
- DICHLOROMETHANE
- SISULFA-SOL
- TEF-SOL
- METHYLENE CHLORIDE
- ALCOHOL
- URESOLVE
- FREON
- SILICONE STRIPPER



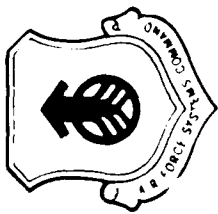
- WOULD A REDUCTION IN THE NUMBER OF SOLVENTS REQUIRED FOR DEPOTTING RESULT IN A COST SAVINGS FOR THE AIR FORCE ?

YES - 15

NO - 9

62%

38%



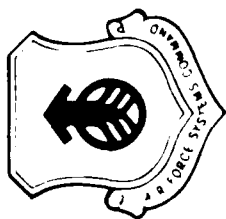
- SILICONES AND POLYURETHANES
SOMETIMES REQUIRE A PRIMER BEFORE
POTTING. WOULD THE APPLICATION OF
A PRIMER BE ACCEPTABLE?

YES - 37

NO - 9

80%

20%

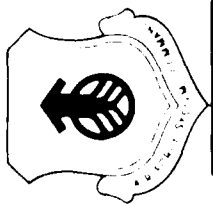


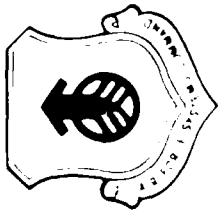
● SHOULD THESE MATERIALS BE USED FOR POTTING COMPOUNDS?

	<u>YES</u>	<u>NO</u>	<u>NO OPINION</u>
EPOXIES	6	22	25
SILICONES	27	2	25
POLYSULFIDES	7	8	38
POLYURETHANES	18	4	31

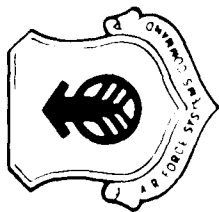


SUMMARY

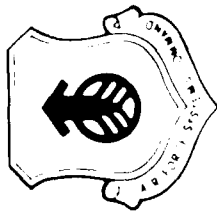




- EXISTING POTTING COMPOUNDS PREVENT ECONOMICAL REPAIR
- POTTING COMPOUNDS ARE FREQUENTLY APPLIED UNNECESSARILY
- POTTING COMPOUNDS SHOULD BE TRANSPARENT IF POSSIBLE



- REMOVAL OF POTTING COMPOUNDS BY
BY CHEMICAL MEANS IS PREFERRED
- OVER ONE MILLION DOLLARS THROWN
AWAY ANNUALLY
- NO SOLUTION FOR PROBLEMS ON
EXISTING MODULES



- NEW PROCUREMENT SHOULD SPECIFY:
 - CERTAIN TYPES OF POTTING COMPOUNDS TO BE USED
 - TYPE OF REMOVAL TECHNIQUE AND MATERIAL
 - POTTING BE USED ONLY WHEN ABSOLUTELY NECESSARY

AD-A110 997

AIR FORCE WRIGHT AERONAUTICAL LABS WRIGHT-PATTERSON AFB OH F/8 5/1
AIR FORCE/INDUSTRY REPAIRABLE POTTING MATERIALS WORKSHOP.(U)
NOV 81 B DOBBS

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DATE
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4-82
DTIC

K. Industry Response to Potting Compound Survey

John Ziegenhagen
University of Dayton Research Institute
300 College Park
Dayton, OH 45469

INDUSTRY RESPONSE TO
POTTING COMPOUND SURVEY

15 JUNE 1981

ELECTRONIC MODULE POTTING COMPOUND SURVEY

TOTAL SENT OUT	1,000	
TOTAL RETURNED	61	6%
TOTAL COMPLETED	49	5%

1. DO YOU CONSIDER THE USE OF POTTING COMPOUNDS ESSENTIAL IN THE

PRODUCTION OF HIGH RELIABILITY ASSEMBLIES?

YES	IN ALL CASES	YES	IN SOME CASES	NO
	22%		66%	12%

2. IF YOUR ANSWER TO QUESTION 1 IS "YES IN SOME CASES",
PLEASE STATE THE CRITERIA USED IN MAKING YOUR DECISION THAT A
POTTING COMPOUND IS OR IS NOT ESSENTIAL AND WHAT MATERIAL TYPE IT WILL BE.

CRITERIA

- IS VIBRATION OR SHOCK PROTECTION REQUIRED?
- ELIMINATE CONTAMINATION FROM DEBRIS
- EXTENT AND TYPE OF ENVIRONMENTAL PROTECTION
- HIGH VOLTAGE CONFINEMENT
- THERMAL TRANSFER REQUIREMENTS
- REPAIRABILITY REQUIREMENTS
- IMPEDANCE MATCHING

MATERIAL TYPE

- GROUNDBASE - EPOXY AND AIRBORNE-SILICONE
- SILICONE FOR H.V., EPOXIES AND URETHANES FOR MECHANICAL STRENGTH

3. WHAT DO YOU CONSIDER TO BE IMPORTANT FUNCTIONS OF POTTING COMPOUNDS?

- ENVIRONMENTAL PROTECTION
- PROVIDE SUPPORT AND STRENGTH
- PREVENT CORONA AND ARCING
- DAMPEN AGAINST VIBRATION
- MOISTURE BARRIER
- MATCHING IMPEDANCE
- TRANSFER HEAT
- ADHESION
- THERMAL EXPANSION OR CONTRACTION
- COVER IDENTITY OF PARTS
- TAMPER PROOF
- EASE OF APPLICATION
- REPAIRABILITY
- LOW TEMPERATURE CURE
- NO DEGRADATION IN HOT HUMID WEATHER
- NO OUTGASSING
- FUNGUS RESISTANCE

4. DO YOU USE POTTING COMPOUNDS ON ANY MODULES CURRENTLY
IN PRODUCTION?

YES COMMERCIAL APPLICATION 45%

YES MILITARY APPLICATION 78%

NO 16%

5. ARE YOU PLANNING ON USING POTTING COMPOUNDS IN FUTURE
ELECTRONIC SYSTEM DESIGNS?

YES	COMMERCIAL APPLICATION	45%
YES	MILITARY APPLICATION	71%
NO		20%

6. IF YOU USE OR ARE CONSIDERING THE USE OF POTTING COMPOUNDS,
PLEASE DESCRIBE THE POLYMERIC TYPES AND INDICATE IF THEY
ARE TRANSPARENT OR OPAQUE.

- POLYURETHANE AND EPOXY SYSTEMS (BOTH CLEAR & OPAQUE)
- EPOXIES, URETHANES AND SILICONES (TRANSPARENT & OPAQUE)
- POLYSULFIDES (TRANSPARENT & OPAQUE)
- POLYESTERS (TRANSPARENT & OPAQUE)
- EPOXIES (CLEAR, 3% & OPAQUE, 97%)

7. WHAT DO YOU CONSIDER TO BE THE THREE MOST IMPORTANT PROPERTIES THAT

A POTTING COMPOUND MUST POSSESS?

- MUST BE READILY REPAIRABLE
- NON-TOXIC
- CHEMICALLY INERT AND STABLE
- HIGH ELASTICITY
- VOID FREE
- RESIST ARCING/TRACKING IN H.V. APPLICATIONS
- GOOD ADHESION TO COMPONENTS OVER TEMPERATURE CYCLING
- GOOD ELECTRICAL INSULATION
- EASILY APPLIED AND REMOVED WITH MINIMAL RISK TO THE DEVICE
- FLAME RETARDANT
- LOW SHRINKAGE
- NON-CORROSIVE
- HIGH THERMAL CONDUCTIVITY
- LOW COEFFICIENT OF EXPANSION
- LONG POT LIFE
- ECONOMICAL
- ADHESION TO MYLAR AND ETCHED TEFLON
- FLOWS WELL BEFORE CURE
- CONSISTENTLY REPRODUCIBLE

8. IF A POTTED ELECTRONIC MODULE MUST BE REPAIRABLE
WHICH POTTING COMPOUND WOULD YOU RECOMMEND?

- LOW DUROMETER URETHANES AND SILICONES
- CLEAR SILICONE ELASTOMER
- EMMERSON CUMMING 2741 AND 2651
- G.E. RTV-615
- U.S. POLYMERIC V-370
- M+T CHEMICALS URELANE 5754
- SYLGARD
- POLYSULFIDE
- FLEXIBLE EPOXIES
- ACRYLIC
- ALIPHATIC AMINE CURED EPOXY
- POLYURETHANE FOAM

9. WHAT ELECTRONIC MODULES PRESENTLY BEING POTTED COULD NOT BE POTTED
IN REPAIRABLE POTTING MATERIALS? WHY?

- NONE KNOWN
- MODULES WHOSE EXTERNAL CASE IS FORMED BY POTTING MATERIAL
- WIRE WOUND COMPONENTS WHERE WIRES MUST BE HELD RIGID
- OPERATIONAL AMPLIFIERS - COEFFICIENT OF EXPANSION MISMATCHES
AND THERMAL CONDUCTIVITY REQUIREMENTS
- SOME WOUND COMPONENTS - BECAUSE OF SOLVENT EXPOSURES DURING
CLEANING OPERATIONS
- COILS IN HIGH TEMPERATURE ENVIRONMENTS IMMersed IN OILS - THE
COMBINATION OF REPAIRABILITY, HIGH TEMP RESISTANCE AND CHEMICAL
RESISTANCE DOES NOT EXIST
- HI-REL - BECAUSE SILICONE IS HYGROSCOPIC
- LARGE MASS TRANSFORMER ASSEMBLIES
- HEAVY COMPONENTS WHICH REQUIRE GOOD VIBRATION DAMPENING
- LOW COST - THROW AWAY ITEMS

9. CONTINUED

- CORDWOOD - EXPANSION COEFFICIENT WOULD CAUSE SOLDER JOINT FATIGUE
- CAPACITANCE CONTROLLED MODULES - CHANGES IN THE POTTING DIELECTRIC STRENGTH WILL RENDER THE UNIT USELESS
- ALL PRESENT MODULES - BECAUSE THERMAL EXPANSION/CONTRACTION, MOISTURE/SALT WATER PROTECTION, AND MECHANICAL STRUCTURE INADEQUATE
- TRANSFORMERS
- MODULES WITH HIGH THERMAL CONDUCTIVITY REQUIREMENTS

10. IN YOUR OPINION, WHAT ARE THE MAJOR PROBLEMS CURRENTLY ASSOCIATED

✱ WITH THE USE OF POTTING COMPOUNDS?

- TOXICITY
- LONG CURE SCHEDULE
- TOO EXPENSIVE AND DIFFICULT TO CONTROL
- REPAIR NEARLY IMPOSSIBLE
- INSUFFICIENT DESIGNER KNOWLEDGE OF USE OF POTTING COMPOUNDS
- NONUNIFORM BATCH
- GOOD ADHESION (ESPECIALLY TO WIRE COATINGS)
- SHRINKAGE STRESSES
- MOISTURE PENETRATION THROUGH POTTING OR AROUND LEADS
- VOIDS OR BUBBLES
- PROPER CLEANING OF PARTS

10. CONTINUED

- STRESSES GENERATED BY THERMAL CYCLING
- MAGNETOSTRICTION AT LOW TEMPERATURES
- MOISTURE ENTRAPMENT AT POTTING
- ADDED WEIGHT
- COPPER CORROSION WITH EPOXIES
- REVERSION WITH POLYURETHANES
- REQUIRE HEAT CURE CYCLES

11. DO YOU PERFORM ANY REWORK AND REPAIR OF POTTED ELECTRONIC MODULES?

CIRCLE ONE

Y E S

59%

N O

37%

12. IF YOUR ANSWER TO QUESTION 11 IS "YES", BRIEFLY EXPLAIN YOUR
REWORK/REPAIR PROCEDURES FOR THE TYPES OF POTTING COMPOUNDS
ENCOUNTERED.

- SILICONES - CUT AND DIG OUT
- EPOXIES - CHEMICAL REMOVAL
- URETHANES - CHEMICAL REMOVAL
- MECHANICAL REMOVAL
- HEATING AND CHIPPING
- HOT KNIFE
- X-RAY DETERMINES BEST EXCAVATION SITES

13. DO YOU BELIEVE THESE SAME PROCEDURES IN QUESTION 12 COULD BE
RECOMMENDED FOR REWORK/REPAIR IN THE FIELD (OR OPERATIONAL LEVEL)?

CIRCLE ONE. WHY?

YES 27%

- THIS CAPABILITY IS NECESSARY
- ESPECIALLY FOR SILICONES
- ONLY IF MATERIAL EASILY APPLIED

NO 45%

- LACK OF EQUIPMENT
- REQUIRES RIGID SAFETY CONTROL
- TOXIC SOLVENTS
- HIGH SKILL REQUIRED
- RELIABILITY LOW
- TOO COMPLICATED
- CLEANLINESS DIFFICULT TO ACHIEVE

14. CAN YOU DESCRIBE ANY APPLICATION OR SITUATION THAT WOULD DEMAND THE USE OF POTTING COMPOUNDS AS THE ONLY METHOD OF SOLVING A PACKAGING PROBLEM?

- HI TEMPERATURE THERMOCOUPLES
- IN MANY CASES, POTTING IS MOST COST EFFECTIVE
- FLEXIBLE PRINTED CIRCUITS
- ACCELEROMETER
- EXTREME VIBRATION
- EXTREME HOSTILE ENVIRONMENTS
- FLAT CABLE ASSEMBLIES
- HIGH VOLTAGE APPLICATIONS (TRANSFORMERS)
- CONNECTORS
- HIGH SHOCK ENVIRONMENT (ELECTRONIC BOMB FUZES)
- IMPEDANCE MATCHING
- WHERE EQUIPMENT MAY BECOME SUBMERGED IN WATER

15. WHICH RESPONSIBILITY DO YOU HAVE RELATIVE TO POTTING COMPOUNDS
AND ELECTRONIC MODULES? CIRCLE ONE.

ENGINEERING

84%

PRODUCTION

29%

ADMINISTRATION

2%

16. COULD YOU MEET MILITARY OR HIGH RELIABILITY REQUIREMENTS IF THE USE OF
 POTTING COMPOUNDS WERE PROHIBITED OR ONLY SILICONES WERE PERMITTED
 WHERE POTTING WAS NECESSARY? EXPLAIN.

YES 41%

NO 59%

- | | |
|---|--|
| • SILICONES WORK IN SOME APPLICATIONS
BUT MANY REQUIRE EPOXIES | • BARE UNITS COULD NOT SURVIVE
ENVIRONMENTAL HAZARDS |
| • ADD FILLERS TO SILICONE | • SILICONES HAVE DEFICIENCIES DUE
TO LARGE COEFFICIENT OF EXPANSION |
| • RTV RESINS ARE MAJOR MATERIAL
IN USE | • SILICONES EXHIBIT POOR RESISTANCE
TO WATER VAPOR AND EPOXIES ARE
NECESSARY |
| • WOULD COST CONSIDERABLY MORE | • SILICONES DO NOT PROVIDE TENSILE
STRENGTH |
| | • SILICONES UNSUITED TO 90% OF
CURRENT MILITARY PRODUCTION |
| | • SILICONES DO NOT HAVE GOOD ADHESION |
| | • NOT RESISTANT TO CERTAIN FLUIDS |

17. PLEASE MAKE ANY OTHER COMMENTS YOU FEEL ARE PERTINENT TO THE SUBJECT OF
POTTING COMPOUNDS.

- OPPOSED TO PARYLENE BECAUSE IMPOSSIBLE TO REWORK
- AVOID POTTING MATERIALS WITH COMPONENTS THAT PRECIPITATE
- AVOID HIGH CHLORINE CONTAINING RESINS
- SHELF LIFE SHOULD BE CHECKED
- PRIMERS ARE ESSENTIAL
- REPAIRABILITY IS A NICE CONCEPT AND SHOULD BE USED MORE - BUT IT IS TOO RESTRICTIVE AND NOT PRACTICAL FOR TOTAL PRODUCTION APPLICATIONS
- MIL-SPEC MATERIALS SCARCE
- OUTGASSING OF MATERIAL IN SPACE APPLICATIONS
- POLYSULFIDES ARE ECONOMICAL AND HAVE GOOD ADHESION
- POLYURETHANES HAVE HIGH TEAR STRENGTH AND ARE IDEAL FOR GROUND SUPPORT EQUIPMENT
- TOO OFTEN THE ELECTRONICS DESIGN ENGINEER IGNORES THE EFFECTS OF POTTING
HE WILL FINISH A MODULE - THEN HAND IT OVER AND SAY "PLEASE POT"
- ENCAPSULATION IS A COST EFFECTIVE MEANS OF INSURING THAT THE FUNCTION OF THE DEVICE IS MAINTAINED FOR YEARS.

SECTION III

CONCLUSION

The Repairable Potting Materials Workshop indicated that the Air Force would definitely benefit from standardization of potting materials for electronic assemblies. Air Force personnel in our ALCs state that large dollar savings would result from the repair of many high cost electronic modules currently discarded as non-repairable. Industry reports that several potting technologies are available which provide repairability and maintain high reliability. The cost savings resulting from elimination of the many different potting materials and solvents by standardization would be an additional benefit for the Air Force.

It was generally assumed that a silicone material with appropriate fillers would best serve as a standard potting material. Everyone agreed that no one potting material is adequate for every application but a large spectrum of applications could utilize the repairable silicones as a standardized potting material for electronic modules.

DAI
FILM